Richards Topical Encyclopedia

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VOLUME TEN

NEW YORK
THE RICHARDS COMPANY, INC.

PRINTED AND BOUND IN THE U. S. A. BY
KINGSPORT PRESS, INC., KINGSPORT, TENN.

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VOLUME X

COMMUNICATION

(For specific facts relating to this subject consult the Index)

The story of communication is presented here in chronological order, beginning with the origin of language and ending with television. The reader who follows this order will gain a clearer understanding of the way in which our present methods of communication grew out of the past When we understand the story of the telegraph and the telephone, radio and television are more easily understood. Each was a step in advance of its predecessor, and they all appeared in the order in which they are here presented.

TRANSPORTATION

(For specific facts relating to this subject consult the Index)

Our plan of presenting Transportation enables the reader to follow the development of methods of transportation from primitive times to the present. Each unit explains an important step, and the units are arranged in chronological order.

INVENTION AND APPLIED SCIENCE

(For specific facts relating to this subject consult the Index)

COLOR PLATES

KEY TO PRONUNCIATION

ā, as in māte
a̍, as in sena̍te
â, as in hâir
ă, as in hăt
ä, as in fäther
ȧ, a sound between ä and ă, as in cȧstle
ch, as in chest
ē, as in ēve
e̍, as in re̍late
ĕ, as in bĕnd
ẽ, as in readẽr
g, as in go
ī, as in bīte
ĭ, as in ĭnn
k, as in key
K, the guttural sound of ch, as in the German *ach*, or the Scotch *loch*
n, as in not
N, the French nasal sound, as in *bon*
ng, the English nasal sound, as in strong
ō, as in bōne
o̍, as in Christo̍pher
ô, as in lôrd
ŏ, as in hŏt
oi, as in toil
o͞o, as in so͞on
o͝o, as in bo͝ok
ou, as in shout
s, as in so
sh, as in ship
th, as in thumb
th̶, as in th̶us
ū, as in cūre
u̍, as in accu̍rate
û, as in fûr
ŭ, as in ŭs
ü, a sound formed by pronouncing ē with the lips in the position for o͞o, as in the German *über* and the French *une*
zh, as in azure
', an indication that a vowel sound occurs, but that it is elided and cannot be identified, as in apple (ăp''l)
A heavy accent (′) follows a syllable receiving the principal stress, and a lighter accent (′) follows a syllable receiving a secondary stress.

Old sailing ships like this one have long since disappeared from the crowded lanes of ocean travel, but they still sail bravely on across the pages of the poets and find safe harbor in the imaginations of all mankind.

Reading Unit No. 1

HOW IS A LANGUAGE MADE?

Note: For basic information not found on this page, consult the general Index, Vol. 15.

For statistical and current facts, consult the Richards Year Book Index.

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Summary Statement

Chinese and Indo-European are the parent languages from which most of the languages of the world are descended.

Photo by Gramstorff Bros.

Do you believe that they are talking together? Whether they both can talk or not, they certainly come to an understanding of some kind, for children and dogs seem to be made to get along together.

HOW IS *a* LANGUAGE MADE?

Here Is the Strange Story of the Way That Languages Were Born and Grew Up

WHEN baby says his first word it is a great day in the family. And so it should be, for every time a baby says his first word it is an anniversary, or birthday, of one of the greatest events in human history—the first saying of the first word of all.

Of course that first word of all was spoken so long ago that we can only guess what word it was and how it happened to be spoken. Learned men have spent much time in puzzling over the problem as to how the first word came to be spoken, and they have devised four theories, or guesses, as they might be called, to account for it. These four theories have delightful names—the bow-wow theory, the pooh-pooh theory, the ding-dong theory, and the goo-goo theory.

One of these great thinkers, trying to decide how the first word came to be spoken, took a look at the animals. He saw that the dog has a sort of language—a yelp of pain or fear, a growl of anger, a bark of excitement. The bird too has its language—a note to call to its mate, and another to drive away an enemy from the nest.

Now everyone knows that primitive man was a great imitator. Why may he not have begun using a bark-word to point out the dog, a song-word to mean the bird, and so on? These sounds were continually hitting his ears, and why should he not have begun his own talking by imitating them? Tiny children even nowadays speak of the "bow-wow," the "mew-mew," the "quack-quack," and so on.

That sounds all very well, said the next great thinker. It is quite likely that dogs were named bow-wows in the early days of the race of man. But were animal names the *first* words people would need? No,

certain other names—names for food, for warning, for love and other feelings—would probably be needed long before men would think of wanting names for the animals.

And so this second guesser looked about him and found that people are always exclaiming over their feelings. If you hit your finger you are apt to say *ow*, and if you are surprised you may probably say *oh*. So certain exclamations such as these may well have been the first words, said the pooh-pooh theory. Men would be needing such exclamations from the very earliest times.

Yes, but you must remember that *ow* and *oh* are not really words at all, says another guesser. They are like the dog's yelp of pain, which is very different from language. Language must tell somebody something. When the dog yelps he does it just to relieve his feelings, and not to tell anybody anything. In the same way, man might say *ow* or *oh* before he ever really talked to anyone. No, said this third thoughtful guesser; let us decide that speech just grew of its own accord out of the need for it. Man's mind was like a bell; when it was struck it rang, "ding-dong!" Words were the ringing of the bell which was man's mind.

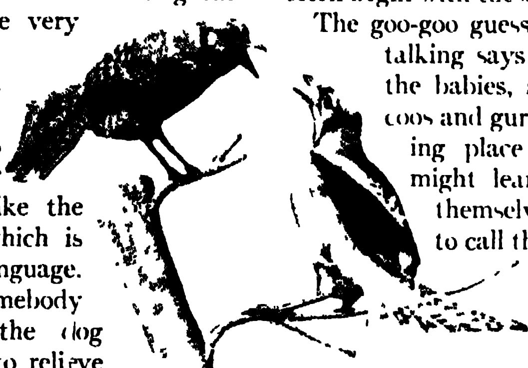


Photo by Nature Magazine

A heated conversation, which both parties understand.

This ding-dong guess about language sounds very deep and thoughtful, but it does not explain things very well. It just says that language began because it began. It is not nearly so reasonable really as the fourth guess, which is about babies.

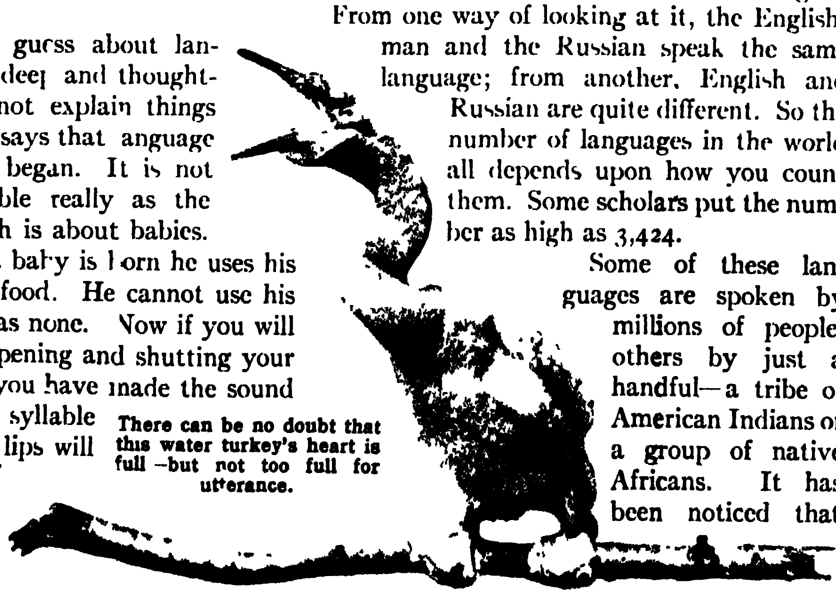
From the time a baby is born he uses his lips in getting his food. He cannot use his teeth because he has none. Now if you will make a noise by opening and shutting your lips, you will find you have made the sound *m*, or perhaps the syllable *ma*. The baby's lips will easily say *ma-ma* for him long before he knows what it means, and it may well be that this word *mama*, or something very like it, has been used from the very dawn of speech, borrowed from babies who were just exercising their lips.

Now try opening and shutting your lips with a little explosion, and you will find that you have said something like *p* or *b*. In the same way that the baby naturally says *ma-ma*, he may say *pa-pa* or *ba-ba* without really meaning to. In a great many languages the words that babies use often begin with these lip sounds *m*, *b*, and *p*.

The goo-goo guess at how people started talking says that it all began with the babies, and that these natural coos and gurgles are really the starting place of speech. Mothers might learn from babies to call themselves *mama*, and fathers to call themselves *papa;* and the whole of human language might have started from this simple beginning.

In the world to-day there are two really great languages, or rather groups of languages, and we shall tell about those in a minute. Besides these there are several thousand different languages spoken in the world, but just how many is difficult to say, because it is hard to tell just where one language ends and another begins. From one way of looking at it, the Englishman and the Russian speak the same language; from another, English and Russian are quite different. So the number of languages in the world all depends upon how you count them. Some scholars put the number as high as 3,424.

Some of these languages are spoken by millions of people, others by just a handful—a tribe of American Indians or a group of native Africans. It has been noticed that



There can be no doubt that this water turkey's heart is full—but not too full for utterance.

Photo by American Museum of Natural History

All these animals express themselves freely and often, though not in words—and not always in sounds. Have you never seen two dogs put their heads together an instant and then run off as if by mutual consent?

in cold countries there are fewer different languages than in warmer ones. For instance, all the Eskimo people, living over the vast region stretching all the way from Greenland to Alaska, speak in much the same way; but the Indian tribes living in the single state of Oregon speak over thirty different languages!

A very interesting guess, or theory, has been built upon this fact. Scholars think that in the warmer places children might now and then stray off by themselves and live to grow up and have children of their own, thus starting a new tribe. If they were young enough when they strayed away, these children might not have learned much of their parents' speech and might invent new words of their own, so that a new language would then be born. Of course this process would be impossible in a cold climate, where stray children could not keep alive.

The two greatest languages in the world to-day are really families or groups of lan-

guages. One, the Chinese, is spoken by over 400 million people living in China. The other, the Aryan (är'yăn) or Indo-European, is spoken over practically all of Europe, North and South America, and Australia, and is used or understood by over 700 millions of people. Over two hundred and fifty millions speak or understand the English language alone, and English is a dialect of the Indo-European, or Aryan, family of languages. Did you know that you yourself speak Indo-European?

At some time, so long ago that no one nowadays has much idea precisely when it was, Indo-European, or Aryan, was a single language spoken by a few thousands of men and women who lived in a single region - probably in the mountainous parts of India. Now there was nothing particularly different or better in the words or the sounds of this Aryan tongue, to make it worthy to sweep the modern world. What was different about Aryan was that the people who spoke it were not exactly like their neighbors. They were more intelligent; they could think and act more quickly. They were fond of travel too, and rather liked fighting, particularly when they won, which often happened.

Photo by American Museum of Natural History

How much of the baby's language can you understand? No one ever taught him what to do when he wants his bottle or when he is thoroughly pleased, but anyone who has ever known a baby will agree that he expresses himself on certain points just as effectively as if he had command of three languages.

How Words Travel and Change

These original Aryan people - we don't know what they called themselves, but we have given them the name of Aryans—sometimes sent out armies here and there on expeditions. Sometimes, no doubt, these armies were wiped out, but often they conquered and returned home laden with rich spoil. Sometimes an Aryan army would like the country it conquered better than it liked its home country, and then it would decide not to go back but to stay in the new kingdom. Soldiers and captains would settle there and marry and have children, until perhaps after a long time they would be strong enough themselves to send out their own armies to other foreign lands for conquest and perhaps settlement.

Let us see what these changes would do to the Aryan language. We shall suppose that one army of Aryan-speaking people has pushed its way clear to Palestine. There it fights with the people who have already settled the land, and wins. Some of these Palestinian natives are killed; others are made slaves. When the invading army decides to settle permanently, the soldiers take many of the native women as wives.

And right here language changes will start. Here is an Aryan-speaking soldier who takes a native Palestinian wife and has a fine family of children. He teaches his wife his own language, of course, but he leaves it to her to teach the children. She does the best she can, but she finds some Aryan sounds difficult or impossible to pronounce. Perhaps she is not used to the sound *th*, and calls it *z*, as many Frenchmen learning English do to-day. All the children learn *z*, not *th*. She makes some mistakes in Aryan grammar, too, since she has no chance to go to school and learn everything correctly. The children make the same mistakes—poor things, how can they know the difference?

Father Time Plays Strange Tricks

And all the other native mothers are apt to teach their children *z* for *th*, and to make the same mistakes in grammar. And so there grows up a whole crop of children who think that *z* is good Aryan, and who teach it to their children. And as the population grows, and other neighboring tribes are conquered and enslaved, other changes come in.

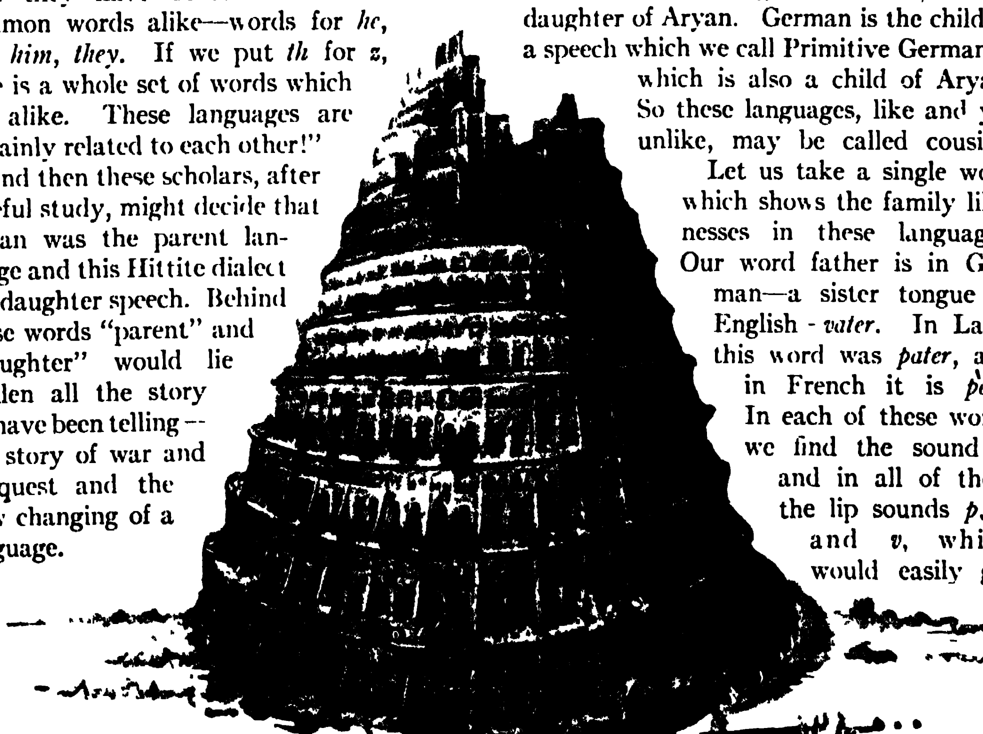
And after a thousand years or so, someone from the original kingdom which sent

out, the first army wanders through this new kingdom and finds that he cannot understand its language at all. It isn't so much the words themselves that have changed, but the way of saying them is so different that they do not sound a bit the same. Neither do the people look like Aryans any more. Perhaps they have dark eyes and black hair instead of blue eyes and light hair. They have even changed their racial name, and now called themselves Hittites, or something like that. The traveler might pass from one end of their kingdom to the other and not recognize that these people ever had been Aryans in speech or in looks.

The Roots of the Language Tree

Thousands of years later, wise men might compare Aryan to this Hittite speech and exclaim, "They are the same! The sounds are changed about, the grammar has become different, but underneath they are the same. See how much alike are the words for *one, two, three, four!* And they have other little common words alike—words for *he, she, him, they*. If we put *th* for *z*, here is a whole set of words which are alike. These languages are certainly related to each other!"

And then these scholars, after careful study, might decide that Aryan was the parent language and this Hittite dialect the daughter speech. Behind these words "parent" and "daughter" would lie hidden all the story we have been telling—the story of war and conquest and the slow changing of a language.



No one ever took a photograph of the Tower of Babel, or made a drawing of it, but this is what one artist thinks it might have looked like. No matter what was its architecture, or whether or not such a tower was ever built, the story shows that early men found people of other nations quite as hard to understand as we do, and were a good deal more puzzled than we are to make out how all those languages came about.

Since the Aryan-speaking people were so active and so restless, many daughter tongues began to spring up in many lands. One, called Sanskrit, developed in India. The Aryan tongue went to Persia, to Greece, to Italy, even to far-away France and England. As they marched they fought and conquered many races, and the slow process of language change began and went on, until an Aryan-speaking man living in Greece could not possibly have understood a man of Persia, although we can see now that the two languages are the same underneath.

And then the people using these daughter languages began to send out armies and settle far countries and marry and trade with each other and carry on the business of life. And so languages arose which we might call granddaughters of the original Aryan, and cousins to each other.

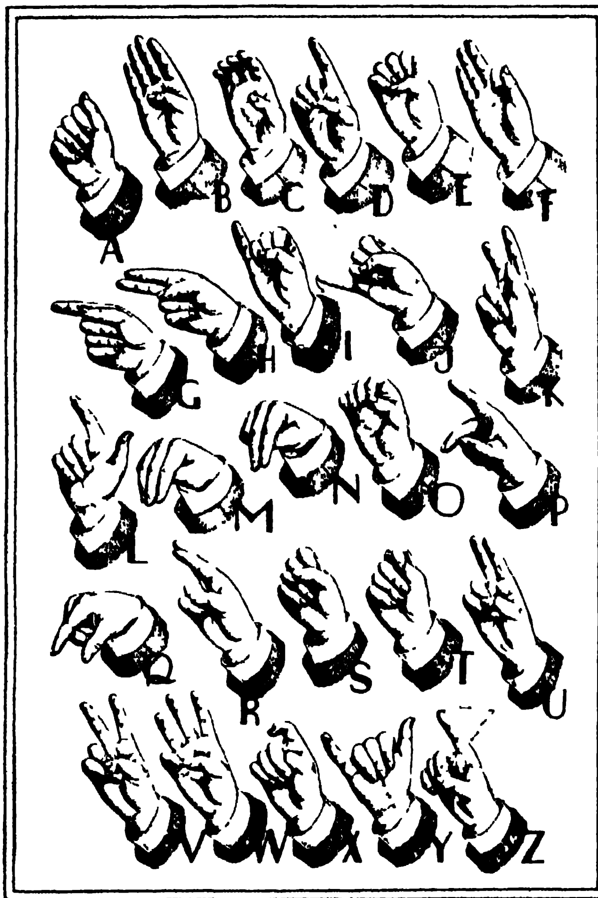
German and French are two such languages. They are cousins to each other. French is a daughter of Latin, itself a daughter of Aryan. German is the child of a speech which we call Primitive Germanic, which is also a child of Aryan. So these languages, like and yet unlike, may be called cousins.

Let us take a single word which shows the family likenesses in these languages. Our word father is in German—a sister tongue of English - *vater*. In Latin this word was *pater*, and in French it is *père*. In each of these words we find the sound *r*, and in all of them the lip sounds *p, f*, and *v*, which would easily get

mixed or interchanged with each other.

What a fascinating game it must have been to the scholars of about a century ago, to work out these language kinships! Before that time people had never bothered very much about how languages grew, but in the early 1800's men began to study out the connections between the different Aryan languages, and they found many interesting things.

Jacob Grimm, whose fairy tales you have probably read, was an earnest student of languages. He worked out a chart or plan of the regular changes between Greek or Latin and the German group of languages. For instance, his table included the fact that when a word had *p* in Latin—as in *pes*, the word for *foot*—in German and English this word would have *f*—as in *fuss*, *foot*. Latin *k*—as in *canis* (ka'nĭs), the word for *dog*—would be German and English *h*—as in *hund*, *hound*.



This is the proper way to form the deaf and dumb alphabet. It's not at all hard to learn; and once you know it, you will find that it goes much faster than the fumbling deaf and dumb alphabet that we all learn to make when we are young.

This table of Grimm's is called Grimm's Law. It is not a law really, but just a picture of how certain Aryan-speaking peoples have changed the way they pronounce words.

Later on, other scholars added to our knowledge of the family relationships in the various Indo-European languages, until now we have a very good idea of the likenesses between Persian, Greek, Russian, German, Spanish, Swedish, English, and all the other languages of the great Aryan family..

It was because the people who spoke the Aryan languages were active and restless that their speech came to be used by so great a part of the world. A language is a mirror of the ideas and activities of the people who use it; if they are dull and stupid, it will be so too. The people who spoke Aryan have extended their speech immensely from the little territory in India which was probably its birth place. And among all the Indo-European languages English is the one which is now used by the greatest number of people.

Did you ever try inventing a language of your own? Many children do try to make up some secret language, and some children have even been known to make up a language when none had been taught them. Otto Jespersen, the famous Danish scholar, tells about a pair of twin boys who were left to grow up together without much care and companionship, and who at the age of four had invented a whole language of their own in which they talked freely to each other.

And grown-up men too have tried their hand at making languages. About three hundred years ago Sir Thomas Urquhart wrote a book with the formidable title "Logopandekteison," in which he told about

Official U. S. Marine Corps Photo

In pidgin English these natives on Guadalcanal are trying to talk two marines out of their flashlights. Pidgin, in one form or another, is spoken by millions in the South Pacific. It is a very simple language a combination of English words and sounds which the natives have picked up from traders and missionaries, plus bits of native dialect. One tribe begins the Lord's Prayer like this· "fader bilong mifelo, yu stop long heven — Ol i santum nem bilong yu Kingdom bilong yu i kam . . ' There are many such trade dialects, all of them born when members of a great trading nation try to make themselves understood by a simple people.

a language he had invented. But as the book did not give the language itself, we do not know very much about it

Many people nowadays think it would be a good thing if everyone could learn to use the same language. Certainly it would keep nations from fighting so much with one another, because peoples talking alike are not so likely to have misunderstandings. For that reason men in recent years have begun to dream of a universal language, a world-wide speech which should make all men brothers.

Several men have devised languages intended for world use. The best-known of these languages is Esperanto (ĕs'pĕ-ran'tō), invented in 1887 by Dr. L. L. Zamenhof, a Polish Jew. Ido (ē'dō), a simplified Esperanto, was invented by a group of linguists in 1907. Whether one of these, or any artificial language, will ever become really a universal language is a question.

At present English seems to have a better chance to become the speech of the whole world English is simpler and easier to learn than French or German or most of the other natural languages. It is spoken by two of the world's greatest nations and is the native speech or the governmental language of over a quarter of the world's inhabitants. In 1932 a group of Englishmen working under C. K. Ogden gave us Basic English, a simplified form of English for use in trade, in scientific articles, in diplomacy, and on the radio. It is clear and is a complete language—that is, anything can be expressed in it—and it contains only 850 words plus some 50 words, like "automobile" or "volt," which are the same in all languages. It is as easy to use as the artificial languages are, and may have a useful future.

Reading Unit
No. 2

THE RICHES OF THE ENGLISH TONGUE

Note: For basic information not found on this page, consult the general Index, Vol. 15.

For statistical and current facts, consult the Richards Year Book Index.

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How does a language borrow words from other languages?
How are frequently used long words shortened?
How many languages are used when we speak English?

Picture Hunt

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Summary Statement

A language is always growing as long as people speak it. So English loses old words, borrows others, and invents new ones.

Photo by Philip Gendreau, N. Y.

The English language was made by a nature-loving people and is exceedingly rich in words for woods and streams and other natural features. Beautiful spots like this one on Derwentwater in the famed English Lake region have always drawn the English poets and so have helped to shape the English tongue. Near here lived Wordsworth, Coleridge, Southey, and Matthew Arnold. And here, says the Venerable Bede, St. Herbert lived.

The RICHES *of the* ENGLISH TONGUE

Here Are a Few of the Strange Ways in Which Our Beautiful Language Has Come to Us from the Ends of the Earth

IF YOU could be carried back nearly four hundred years to the delightful time when Will Shakespeare was a little boy in Stratford, and if you could hide behind a tree and listen to him talking to his mother, you might be surprised to find that it would be hard for you to understand what he said. Some words he would pronounce as many Irishmen say them today. He would say *mate* for *meat* and *tay* for *tea*. And there would be other differences, too, which would be even more puzzling. For our way of speaking English has changed very much since Shakespeare's time.

And if you had trouble understanding Will Shakespeare, how much would you understand if the clock of history should turn back over a thousand years and you should find yourself sitting at meat with good King Alfred and his retainers in the great hall at Winchester? You could not join in the conversation at all. Except for a few little words—*and, hat, gold, met*—the English that Alfred spoke would sound to you like a foreign language.

Here are some words that King Alfred must have spoken often: *Fæder ure þu þe eart on heofonum, si þin nama gehalgod.* This means "Our Father, who art in heaven, hallowed be thy name."

So you can see that the pronunciation of English words is always changing. And so are the words themselves. New words are being added to our language and old ones taken away; and the new and old ones are always changing more or less in what they mean. They are falling sick and getting well, being born and dying, quarreling and making friends again, just like the people who speak them. Nothing is much more human than a word.

The story of the English language begins with Hengist and Horsa, about fifteen hun-

dred years ago. In their long, swift boats, full of strong fighting men, these two warriors swooped down from the northwest of Germany upon England, or Britain, as she was called then. And with them in their long boats they brought something more precious than the gold arm rings they wore, more powerful than the hammered swords they carried. They brought the English language.

Hengist and Horsa came to fight for the British king Vortigern, to help him against his enemies the Picts. But when those Germanic soldiers—"Angles" and "Saxons" and "Jutes," they were called-- saw what a good land Britain was, and how weak the Britons were, they began to fight against Vortigern instead of for him, and to take the land for themselves. They succeeded so well that after a few centuries Britain was not "Britain" any more, but "England"—or "Angleland"—the land of the Angles. And England it has remained ever since.

But that early Anglo-Saxon tongue that migrated to England on the lips of those bold conquerors was not at all like its great-great-grandchild which we speak to-day. It was even more different from it than the speech of King Alfred was. What has happened between the time of Hengist and Horsa and our own day to make the English language change so much? Well, there are several very interesting answers to that question. First of all, the German tribes were not the only people who conquered England. Those Angles and Saxons and

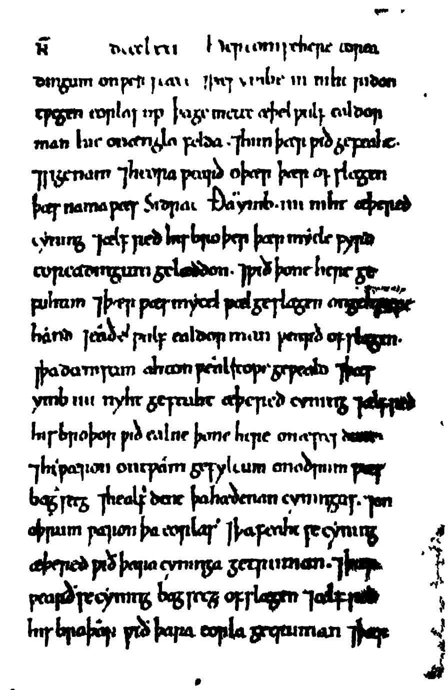


Photo by British Museum

This is the way English looked eight hundred years ago. But in case you do not know your mother tongue quite well enough to read it, we will tell you that it is the thrilling account of how the English king Ethelred and Alfred his brother defeated the Danes at the Battle of Ashdown in 871. This was the Alfred who was later to become one of England's greatest kings, and this is the battle that took place in famous White Horse Vale, dear to the heart of everyone who reads "Tom Brown's School Days." The page shown here is taken from the Anglo-Saxon Chronicle, the first history of England in the English tongue, and was written by hand on vellum not long before the year 1100. It is now in the British Museum, in London.

Kentishmen were given a bit of their own medicine when, some three hundred years later, the Danes began coming to England to see what their swords could win. They liked England so much that thousands of them moved over to stay, bringing their wives and children and taking or making farms for themselves, where they could live in families and be happy.

The language the Danes spoke was not so very different from English. They called their little boys *sunr*, while the Englishmen called theirs *sunu*. By and by people who kept hearing both *sunr* and *sunu* got the two mixed. They did not know which was the right way to say the word. So they just used the word *sun*, which was like both. And *sun*, or *son*, the word has remained to this day.

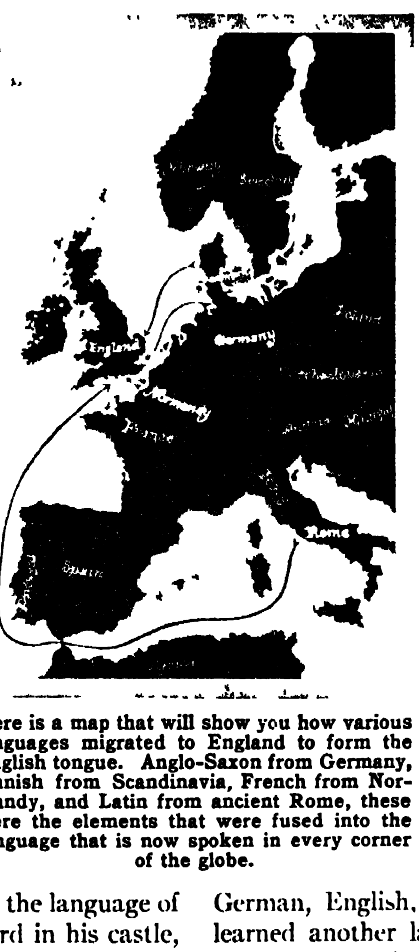
In this way the Danish language changed English. It helped to make our words shorter and more simple. It gave us many of our little words -*skin*, *skirt*, *law*, *call*, and many others. It even gave us our words *they*, *their*, and *them*. In English *he* was *he*, and *they* was *hi*. People were always getting *he* and *hi* mixed, but they could be quite clear about *he* and *they*. So the Danish *they* became an English word.

How Words Get Worn Down

Those Danes gave the English language a big push toward change, but English was changing anyway. Words were growing shorter, as words do when they are used a great deal. We see it happening in families

when they say *Tom* instead of *Thomas*, or *Ben* for *Benjamin*. The Old English, or "Anglo-Saxon," words were rather long, and people in a hurry would not bother with the last parts of them. So *hieran* became *hear*, *wudu* became *wood*, and such a long town name as *Eoforwic*—"the boar's town"—was clipped off by degrees until it turned out to be just *York*. So New York is really the "New Boar's Town." London too is a shortened word. At first it had a Latin name, *Londinium*.

The Danes were not the only men who had a part in moulding our language. In 1066 the Norman—or "North-man"—William the Conqueror came over from France to win England with his sword, and settled down to live there. He brought over hundreds of French lords and soldiers, with their butchers, bottlers—or "butlers" carpenters, and other craftsmen. We still call all these workmen by their French names, for *butcher* and *butler* and *carpenter* are all French words—as are thousands of others that we use.



Here is a map that will show you how various languages migrated to England to form the English tongue. Anglo-Saxon from Germany, Danish from Scandinavia, French from Normandy, and Latin from ancient Rome, these were the elements that were fused into the language that is now spoken in every corner of the globe.

The French conquerors did not care to speak the language of the conquered Englishmen. French became the language of the king in his palace, the lord in his castle, the judge, and the lawyer. Englishmen who wanted to fit into the new government had to learn to speak French, and they did. For almost three hundred years the proud French speech fought the sturdy English tongue for the honor of being the language of all England.

We Borrow Words from Every Land

And both English and French won the battle! For we all speak both of these languages to-day. When you call a calf a *calf*, you are speaking English. When you say the "butcher" sells "veal"—calf meat—you are using two French words, ***butcher*** and ***veal***. For what the English did was just to add thousands of French words to their own thousands of English-Danish ones. They took a great deal of the French language into English, and made one speech out of the two. And that was the best way for the language fight to end!

Since the time of William the Conqueror no foreign nation has settled in England, and so no languages have mixed with ours in the way the Danish and French did. But English has gone right on changing just the same. It has gone on borrowing words from French and from many another language. And it has borrowed thousands of words from languages that are dead, as well as from those that are still living. In this way it has taken over a large part of the Latin tongue.

In the years from the beginning of our calendar, at the birth of Christ, to the time of Shakespeare, Latin was the one language that everyone wanted to add to his own. Whether a man spoke German, English, French, or Spanish, if he learned another language it was certain to be Latin. Latin was the language of the church, which during most of those years was the seat of learning, much as our colleges and universities are to-day; and the learned books in all the countries were Latin books. You had to learn Latin if you wanted to be educated and to talk and write to people in other parts of the world.

So words were taken over into every language, but especially into English, for the English people have always had the habit

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All the learning that has come down to us from the long ago we owe to painstaking monks, like the ones above, who toiled in heat and cold, in sickness and in health, copying the books in their monasteries. Sometimes they grew sleepy and sometimes they grew bored and sometimes they did not understand what they were copying, so they made mistakes here and there. But if it were not for their labors we should not know what our language was like in its childhood, nor should we know so much about the past.

of taking up whatever seemed good and useful In the years from 1200 to 1700, thousands upon thousands of Latin words were welcomed into English. About a third of the words in our dictionaries to-day are Latin words, though of course nearly all of the very common little words, the ones we use over and over every day, are and always have been English. We need Latin words to say complicated things with, but we talk mostly with English, Danish, and French ones.

How Many Languages Do You Speak?

Perhaps it just came to be a habit of the English people to take words from other languages into their own. Of course we should rather think it was the wisdom of the English, their quick wits and restless intelligence. But whatever the reason may be, Englishmen have gone all over the world collecting good and useful words, and have brought those words back to live at home in England. There is no language, past or present, which has so great a wealth of words from all over the earth.

When you say *candy* you are speaking Arabic, and when you ask for *turkey* you are talking Persian When your mother makes a cake she may speak Hebrew in *cinnamon*, Greek in *butter*, Sanskrit in *ginger*, French in *flour*, Italian in *soda*, and good old English in *milk* and *egg*. Your *face* is French, but your *nose* is English. Your *dollar* is German, your *penny* English, and your *dime* Latin. Every time you talk, you are using words from all over the world.

Besides the thousands of words which English picks up from the ends of the earth, many new words come pouring into it from still other sources And the ways in which new English words are made up are so interesting that you must hear about a few of them

Where New Words Come From

Once in a while a word is made by some man who just takes sounds and makes them into the pattern of a word. Such a word is *kodak*, which was made up in America not so very many years ago. Another is *gas*, which a Dutch scientist invented, although

he did have a Greek word in mind as a model. It is very seldom that a new word gets made out of whole cloth, like *kodak*.

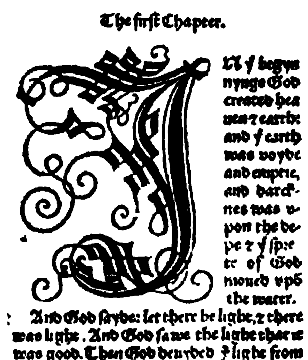
Many words just echo noises. See how many you can think of like *pop, bang, mew, moo, buzz, purr, whiz*. Such words are being made up all the time, and there are hundreds of them in English.

Many words are named after people. If you speak of *bloomers*, you are using the name of Mrs. Bloomer, of New York State, who wore them about a hundred years ago. If you wear *knickers*, you are using the name of an imaginary Dutch gentleman. For Washington Irving, when he wrote a comic history of the city of New York, pretended that it had been written by one Diedrich Knickerbocker—and so the ample trousers that those staid old Dutchmen wore came to be called by the name of the supposed author.

Did you know that *canary* really means *dog bird?* When a name was given to the Canary Islands, they were called Canary from a Latin word *canis*, meaning *dog*. This was because of the large dogs there. These islands also held flocks of lovely little yellow birds, and the birds were given the dog name, *canary*, because that was the name of the islands where they lived.

These are a few of the ways in which new words are born into English. But the commonest way to get new words is to make the old ones over—by putting them together or taking them apart or changing their meanings.

Below you see Tyndale at work on his translation of the New Testament (1525) and the Pentateuch (pĕn'tà-tūk) the first five books of the Old Testament. Tyndale worked from the original Greek and Roman texts, but consulted Latin versions, such as the Vulgate of St. Jerome, finished a little before 400 A.D. Tyndale's work was the foundation of the King James Version (1611), now used in most of our churches. More than any other book it has helped to make the English language what it is today.



The first Chapter.

IN the begynnynge God created heauen & earth: and the earth was voyde and emptie, and darcknes was vpon the depe, & the spirite of God moued vpon the water.

And God sayde: let there be lyghte, & there was lyghte. And God sawe the lyghte that it was good. Then God deuyded the lyghte from the darcknes, and called the lyghte, Daye: and the darcknes, Nyghte. Then of the eueninge and mornynge was made the first daye.

Photos by Rischgitz and British Museum

Get your Bible and turn to the first chapter of Genesis. You will find that this page of English from the year 1535 is not so hard to read after all, though some of the letters look strange. It is taken from the first printed English Bible, now in the British Museum, in London. It was translated by William Tyndale and Miles Coverdale, and was the first English Bible translated from the original Hebrew and Greek, in which the Bible was written.

When the locomotive was invented people wanted a word for the new kind of road on which they were going to speed from place to place. So they put two words together and called the new thing a *railroad*, or road of rails. Sometimes it is also called a *railway*

The word *airplane* is two words put together. It means a "plane," or flat thing, which can travel through the "air." Many people nowadays have taken this word apart again and call it simply *plane*.

It is usually a new idea which calls for a new word. And when a new word is needed, very often nothing at all is done but to find some old word and give it the new meaning in addition to its old one. In this way *film*, which is used to mean a thin coating or layer, was taken for the plate in a camera, which has a thin coating of chemical on it; and then it became a name for the whole series of moving pictures that have been taken with a camera. And now this new meaning has nearly swallowed up the old one, for if you tell your friend you have been to see a film, he will never dream of anything except a moving picture.

If you want to track down a single word through some of its wanderings, you might take the simple word "post." At first a post was just a log stuck in the

ground where it could not move. Since it could not move it was often used to show where one man's land ended and another's began; so it came to mean a boundary. Then there came to be all sorts of different posts--gateposts, doorposts, and even whipping posts. In days when prisoners used to be whipped, they were first tied to a post; so to be "condemned to the post" was to be condemned to a whipping. In old times a tavern keeper used to chalk up the names of people who owed him money on his doorpost. Nowadays we put their names in books, but the bookkeeper still *posts* his accounts in his ledger.

Since a post could not move, any fixed point came to be called a post; so we say that a policeman is at his *post* on the corner. And since a post had now come to mean a place, it soon meant a position or job—a *post* in the War Office or the cabinet.

Now when people began traveling, they had to change horses every so often. Wherever they had to change, there was a post for tying the horses. So traveling from post to post came to be called *posting;* and what had first meant "stuck in one spot" came to mean "going from one spot to another." People posted pretty fast, and soon *posting* meant traveling in the fastest way you could. From staying in one place the word came to mean speeding to any other place—or going *posthaste.* Then when people *sent* things from place to place they sent them by post—and a host of words like *post office* and *postman* and *postage stamp* followed. Now we can *post* a letter in an airplane.

But a post can still be a thing stuck in the ground. Now in old days people put notices on posts to be read—they *posted* advertisements and news of all sorts. So when they started newspapers they often called them *Posts*--the *Morning Post,* or the *Washington Post.* And a stick in the ground has turned into a newspaper!

And still these are only a few of the things that *post* has come to mean. How many more can you think of? Look them up in a big dictionary. But mind what you are doing! For this kind of *post* has got all mixed up with another kind which comes from the Latin word *post* and means "after", so when we speak of *postponing* a letter we are using the other word. We may want to write a *postscript,* or "after-writing," to the letter before we *post* it, or speed it along.

Photo by American Museum of Natural History

Here are Columbus's three little boats that found a new world. After them came a long procession of gallant ships in search of land and wealth. They brought over colonists and supplies and took back all sorts of treasure. But of all the things they carried, few were more important than the noble English tongue, which took up little room in the hold but which is nevertheless one of our most priceless possessions. Be glad that you were born to the use of it, and treat it with respect.

If you heard someone call your little sister a "base, puny brat," you would probably be pretty angry. Yet four hundred years ago these were three good, healthy English words, and no one would have minded them. A *brat* was just a child, *base* meant "humble," and *puny* meant "little" or "younger." Today *base, puny,* and *brat* all have a bitter meaning. They have grown sick. They are not pleasant words any longer.

How Words Fall Ill

Many other English words have grown sick in the same way. An *imp* used to be just a child; now it means a mischievous child. A *knave* used to be just a boy, but now a knave is a wicked person.

If some English words have fallen ill, many others have got well. In Shakespeare's time *baby* meant *doll* or *puppet,* and in one of Shakespeare's plays, the great Macbeth calls himself "the baby of a girl"--meaning

Photo by The Knapp Co.

As soon as these first English settlers landed at Jamestown the language they spoke began to take on a new color. They learned many new words from the Indians—and we still use those words to-day.

a little girl's doll. Nowadays *baby* is a pretty word. To-day you can be fond of someone without being ashamed of it, but long ago *fond* meant "weak" and "silly." So *fond* is another English word which has got well.

Our Mother Tongue Goes Traveling

About the year 1500, in England and other countries as well people began to take a great interest in exploring far-away lands. The Italian Columbus had just discovered land in America, and the Englishman Cabot had followed him. During the 1500's many English explorers were busy, and as you know, the explorers were followed by colonists who went to live in the new countries or to seek adventure there. These English colonists, like Hengist and Horsa so many centuries before, carried with them the English language. English sailed to the colonies of North America, of India, Australia, New Zealand—in fact, everywhere that Englishmen went. And so gradually English has come to be used by more people than any other language in the world except the Chinese. Over three hundred million people now use or understand English, and millions are learning it every year.

It is a good thing that English is such a beautiful and useful language, since it has been flung so far over the face of the earth. If it were not strong and capable it would not deserve such an honor. But luckily it is easy to learn, rich in words, and interesting. And there is no language spoken to-day in which such beautiful poetry has been written. We can be very glad of our good fortune in having English for our mother tongue. And we can show our appreciation of our fine and strong language by treating it politely and using it with care.

COMMUNICATION

Reading Unit No. 3

STORIES FROM THE DICTIONARY

Note: For basic information not found on this page, consult the general Index, Vol. 15.

For statistical and current facts, consult the Richards Year Book Index.

Interesting Facts Explained

How dictionaries tell the story of words, 10–17-18

How the meaning of the word "fellow" has changed through the ages, 10–18-19

How different words come from the same root, 10–20

Words that have interesting stories, 10–20-21

Making words fit their meanings, 10–22-23

Lazy words, 10–23-24

How we come to have slang, 10–24-25

Things to Think About

Why do people tend to shorten words?

How many kinds of slang do we use?

How should we use slang in our conversation?

Picture Hunt

Name some of the great dictionary makers, 10–22, 24-25

Name important men who helped to make English what it is today, 10–18-19, 21

Related Material

Why was Esperanto invented? 10–7

Why was Dr. Johnson's dictionary important? 13–195

What was the "Age of Prose and Reason"? 6–75

When were private letters first sent by mail in England? 10–86-87

Are any of the words that the early Colonial settlers borrowed from the Indians still in our language? 10–15

Practical Applications

How do we decide what is correct in spelling and pronunciation? 10–22-25

How do we make new words? 10-20-21

Summary Statement

We cannot tell what many English words will mean in a hundred years' time. We know that they must change in meaning if they are to remain alive.

The name of this picture is "The Old Lexicographer." Now a lexicographer (lĕk'sĭ-kŏg'rȧ-fẽr) is a maker of a dictionary; and no one knows half so many stories of words as he does. People may call him an "old dry-as-dust," grubbing away at roots and stems and endings in queer corners of knowledge, but if he has any imagination at all, what thrilling pictures of history, what a pageant of the singing, talking folk of all the ages, must move before the eyes of his mind! Perhaps we should do better to envy him.

STORIES *from the* DICTIONARY

Tales of How the Little Words We Toss from Mouth to Mouth Have Had Their Ups and Downs and Have Often Come to Mean Something Quite Different from What They Meant at First

DID you know that one of the most fascinating storybooks in the world is—the dictionary? And no wonder it should be so when you come to think about it—for each one of its many hundreds of thousands of words has a story of its own and has passed through many more adventures than you or I have time for in our short lives.

Just because there are so many of these stories, they have to be written very briefly indeed, usually only by a series of signs that mean no more to us than Egyptian hieroglyphics, until we know how to read them. And it is only in the bigger dictionaries that there is room for even that much of a story. But just to give you an idea of how interesting word stories are, we are going to translate a few of them here for samples.

Take, for instance, the word "villain." If you look in a dictionary you will find its story summed up something like this: <F. vilain, serf, <LL. villanus, <L. villa. If we translate this exactly we get: the word "villain" came into English from the French language, where it was spelled "vilain" and meant a serf, or person bound by law to stay on one farm and till it; "vilain" came into French from a late form of Latin, where it was spelled "villanus"; and "villanus"

came into Late Latin from regular Latin by being formed from the word "villa," which means a large farm. Now this is all very well, but the dictionary clearly says that "villain" means "farmhand" and not a free farmhand either; and what is there so villainous about a farmhand? Well, *that* is the story behind the story.

Back in the tenth, eleventh, and twelfth centuries, when English was industriously borrowing scores and hundreds of words from the French—"villain" among them—England was fast borrowing its ways of living, too, from the French-speaking Normans who had conquered the country in 1066. It borrowed the whole feudal system, which meant that a person who worked on a farm really became a serf, or "vilain"; so what more natural than that he should be called by the French name? It did not at first mean that he was particularly wicked.

Photo by the National Portrait Gallery

Geoffrey Chaucer never wrote a dictionary or set up as a scholar learned in words, but no one ever did more than he to make English what it is to-day. For he wrote at a time when there were many dialects of English and when no one was very sure how to spell English words. And people liked what he wrote so well—especially "The Canterbury Tales"—that they followed his example in the use of words.

But it did mean that he had no chance to be more than an ignorant, rough fellow, who had very probably never been taught any morals and certainly had almost no way of getting what he wanted except to steal it. So after all, it was small wonder that as time went on people began to think of a "vilain" as a rather wicked person. And after a long while the word took on its present meaning. Now if we want to use it in its old meaning, to describe a serf in the old times, we often use an old spelling—"villein"—to show what we mean.

Words That Have Changed Their Meaning

So you might say that the whole history of English farmhands was bound up in that little word "villain." There are many other words that have changed as much and tell us as much of the past. "Knave," "brat," "silly," "churl," "cunning," "sly," and "crafty," are a few of them. But let us take "fellow" for another example; it has changed oftener than "villain" has, for once it was good, then it was bad, and now it is indifferent.

In the Old English spoken a thousand years ago or more, "fellow" was made up of two words—"feo," property, and "laga," one who lays. That does not seem to make much sense, does it? But what it meant was a "partner," one who lays down his property beside yours for both to share surely a charming way to say "partner"! So clearly "fellow" was an honorable word in Old English.

While it was still an honorable word, "fellow" was put with other words to make such honorable compounds as "fellowship" and "playfellow." These words, of course, we still use, and we never listen to a campaign orator without hearing much about "fellow citizens" and "fellow Americans" and perhaps "fellow Republicans," or "fellow Democrats," or "fellow Socialists." But we rarely use the word "fellow" alone to mean "companion" or "partner."

For the word long ago fell from its high estate. Indeed, it came to mean "companion in idleness" or "partner in low company," and it continued to mean that sort of thing until about a century ago. It was a great insult to call anybody a fellow—almost as great as to call him a villain. And there was even a saying, "Worth makes the man, and want of it the fellow."

But for some reason the word has now climbed up a little in the world once more.

Many a word we use to-day calls up the memory of Shakespeare and of the great men of his day, some of whom are pictured here. Every great writer helps decide the history of the language, for people keep on reading him and that keeps his words alive. Even so, we sometimes run across words in Shakespeare that are no longer in use or that now mean something else; and as for earlier writers, we often have trouble understanding them without a glossary, or list of unfamiliar words with their modern meanings.

Sometimes it is just an indifferent, informal word for person—"What sort of fellow is he?" Sometimes we speak of an idle fellow or a worthless fellow, but we are just as likely to speak of a good fellow or a jolly fellow. In these last the word holds just a shade of its oldest meaning, for we think of a "good fellow" as a good companion.

The Many Meanings of "Nice"

Sometimes words change their meanings in spite of us, no matter how hard we try to stop them. "Nice" is a good example of this sort of word. Recently it has been changing its meaning again, and many of us have tried to stop it without realizing that it has played the same sort of trick many times before.

When we first meet "nice" it is the Latin word "nescius," meaning "ignorant" or "unknowing." From Latin the word became French, and from French, English. When it first appears in England it is with the meaning "foolish," much as in Latin.

Then Englishmen began to speak of a "nice" person, meaning one who was foolishly particular about little things. From that meaning the notion of foolishness dropped off, and anyone who paid attention to details might be called "nice." And people began to speak of "a nice distinction" or a "nice adjustment," meaning a distinction or adjustment that was very small, delicate, and exact. This meaning the word still holds.

But while holding this meaning, the word slyly began to take on another one, too. It began to mean "excellent" or "agreeable," as it does nowadays in ordinary talk—whether that is because on the whole we like people and things that are exact and careful about details, who shall say? At all events, this was the change so many people tried to stop, because they did not know or did not remember that "nice" had had so many meanings already that it was foolish to say only one was correct.

Where "Canvas" Came From

Indeed, words are always developing new meanings without giving up the old ones. Sometimes this habit of theirs leads to the most astonishing results. Take the two

words "canvas," a cloth, and "canvass," a going about among people to collect money or votes or information. These two are really the same word, and go back to the Latin "cannabis," the name of the hemp plant. Imagine the painted canvas of a great artist and the visits of a community-chest worker both meaning hemp!

When Hemp Became Cloth

It is not hard to see how the name for hemp would come in time to be the name for the cloth made out of hemp, for exactly the same thing has happened with cotton and wool. So when the word passed into French and English it already meant a kind of cloth.

Now in old times people had a way of examining certain things by placing them on a canvas sheet and tossing or shaking them together; and from the name of the sheet this process got to be called canvassing. So what more natural than that the word should later come to mean any sort of examination or investigation? One may canvass the opinions of one's neighbors, that is, one may find out what they think about this or that. Later still, when people went about asking for gifts for an orphans' home or selling tickets for a policemen's ball, they said they were canvassing.

Many Words from One Root

Whole crops of words will be built out of a syllable or two of Latin. There are the words from "sen-," a root meaning "old." Most of them are words showing reverence, for old people have experience and power and ought to have learned wisdom. Since the Romans thought that an old man was the best counselor, they called the reverend assembly that ruled them the "senate." We have taken this word over bodily, and call the more dignified of our law-making assemblies a "Senate," too.

We have also taken over bodily the Latin word "senior," which means "older." Mr. Jones, Senior, is the father of Mr. Jones, Junior. Mr. Brown is the senior, or elder, partner in the firm of Brown and Smith. A senior in college is a member of the class that has been there longest. Seniority rights in the United States Congress mean the rights to place on committees, to be decided by the number of years a congressman has served.

The same Latin word for "old" gave the French their word "sire," literally an old man but in practice a title of rank. The word came over into English, and finally was clipped to "sir," sometimes a title of rank and sometimes just a term of respect—as when we say "Yes, sir," or "No, sir," to men older than we. In modern French the word "sire" has turned into "monsieur," which we translate "mister," but which literally means "my old man"!

Besides all these respectful words from Latin "old" there are a few less respectful ones. There is "senile," from Latin "senilis," which means foolish from extreme old age. Then there is "sirrah," which we often run across in Shakespeare and other older writers; it means almost the opposite of "sir," and was used in speaking to someone for whom one has no respect at all.

Words That Have a Story

Sometimes it is easy to see that there must be a story in a word because the word was originally somebody's name. This may have happened so recently that many people remember it —as when we speak of "macadamizing" a road, naming the process after McAdam, the inventor of it. Oftener it happened so long ago that we are surprised to find out about it - as in "dunce," "hector," "lynch," "kaiser," "vandal," "assassin," "canary," "romance," "sandwich," "panic," and "guy." We shall have to let you look most of these up for yourself, but here is the story of "guy."

This word "guy" is named after Guy Fawkes, an Englishman who conspired against the British government and was executed for treason in 1606. Now that is a surprising sort of person to have had his first name made into a common word. What happened was that English children got into the habit of celebrating every November 5—the day on which the conspirators had planned to blow up the parliament—by burning stuffed figures supposed to represent Guy Fawkes. Not unnaturally they called these figures "Guys." Soon any queer-

Photo by Gramstorff Bros Copyright by H K T

Words have not changed their meaning nearly so fast since the invention of printing. You can see how that would be—there the thing is, in black and white for all to read, and people always have more respect for things they see "in print" than for things they merely hear. So though William Caxton was not one of our greatest writers, like Chaucer or Shakespeare, he had just as much to do with deciding what words we should speak, for he introduced printing into England. Here he is with his assistants working at his press.

looking person came to be called a "guy" after the queer-looking figures, and the expression "guy a person" grew up, meaning to make fun of him or play tricks on him.

In the United States, which does not remember Guy Fawkes so well as do the British lands, the word is not nearly so uncomplimentary, and usually means just a person, a fellow, rather than a queer looking creature. Besides, the word is slang in America, while in England it is not slang at all.

The Queer Story of "Bedlam"

Some words are named after places. One of the most surprising of these is the word "bedlam," which we use to mean any place that is full of noise and confusion. "This room is a perfect bedlam," we say reprovingly when we cannot think for the noise. But did you know that this word is the same as Bethlehem, the name of the town in Palestine where Christ was born? How could such a quiet word as Bethlehem take on such a noisy meaning?

Here is the story. In Palestine in the year 1200 there was a priory, or religious house, which was called the house of St. Mary of Bethlehem. A branch of this house was founded in London in 1247, and when England turned Protestant it became the property of the city of London (1547). The monks of this house had made it their special duty to care for insane people, and the city took over this duty along with the priory. So the Bethlehem priory in London was really an insane asylum.

Clipping "Tongue Twisters"

Now of course insane people are often noisy, and they used to be much noisier in those days, when no one knew how to care for them properly. Often they were treated very cruelly. So it came about that the noise and confusion in this insane asylum were so great that people began to mention it if they were talking about a noisy place. "It is as bad as the Bethlehem asylum," they would say. Little by little "Bethlehem" got shortened to "bedlam"—try it yourself and see how hard it is to say "Bethlehem" several times fast—and as "bedlam" it has become a part of our language.

This business of cutting words down sometimes makes queer sense. Take a pair of

very modern words, for instance—"autobus" and "taxicab." As a matter of fact, we usually cut these still more in our laziness, saying merely "bus" and either "taxi" or "cab." But even the longer forms are very much clipped—the words should really be "automobileomnibus" and "taximetercabriolet." There are two fat mouthfuls for you!

The word "automobile" was deliberately put together not very long ago from the Greek word "autos," or "self," and the Latin word "mobile," or "moving"; thus the whole word very naturally means "a thing that moves itself." "Omnibus" is a form of the Latin word "omnis," or "all," and means "for everybody"; an omnibus or bus, therefore, is a conveyance for everybody who can pile in. Now, put the two together, and you have "autobus"; it means a self-running conveyance for everybody, but what it *says* is "self" plus an ending which might possibly be translated "for"—as if a motor bus were something one ran for oneself alone!

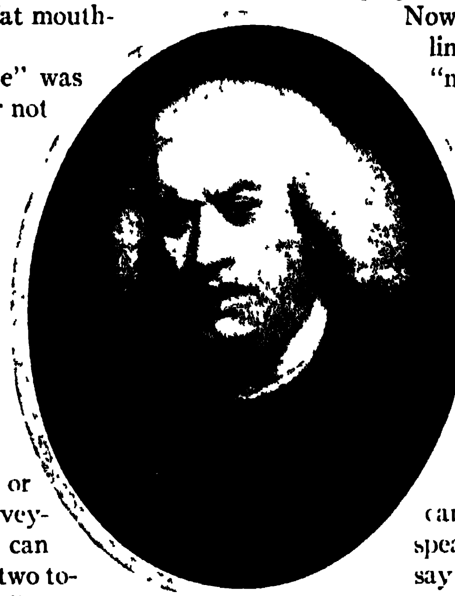


Photo by National Gallery London

Perhaps the most famous of all dictionaries was that of Samuel Johnson, published in 1755. Here is the famous Dr. Johnson himself, whose word on what was correct in speech was long taken as law.

As for the second of our "tongue twisters," the first half of it comes from a word meaning "tax measurer," that is, a machine for measuring how much fare one should pay. The second half, "cabriolet," used to mean a one-horse covered carriage with only two wheels, and before that it may be traced back to an Italian word meaning "leap" or "caper," which itself comes from the Latin word meaning a "goat"—presumably because a goat capers about so lightly. So "taxicab" means a "tax leap"—or shall we say a "fare caper"? Not such a bad name, after all, when we think of how the fare leaps higher and higher as we travel on!

This is barely a beginning in the list of the funny things people do to words as they say them over and over. One odd thing that has happened to several words—all much older than these we have been speaking of just now—is that they have dropped off or put on an "n" at the beginning. "Apron" and "napkin," for instance, are really the same word, which comes from French "naperon." Even nearer to "naperon" is modern English "napery," which means "table linen."

Now a napkin is a little piece of linen, just as it should be; for "nap" means "linen," and "kin" means little, as it does in "lambkin." But how about "apron"? It would be almost exactly like "naperon" if it had an "n" before it but, you will say, it has no "n." True enough, but it had an "n" once; and as a matter of fact, it very often still has one, only it lets the article "a," which comes before it, carry its "n" around for it. To speak plainly, people used to say "a napron," but then they got into the habit of saying "an apron" instead. Exactly the same thing happened in the phrase "an adder," which used to be "a nadder"; and in "an orange," which should by rights be "a norange." Will someone pass the noranges, please?

So some words appropriated the "n" which really belonged to the article. "Newt" used to be "ewt," but people perversely insisted on saying "a newt" when they should by rights have said "an ewt."

Fitting Words to Their Meanings

Another strange thing people do with words is to change them to sound more like other words of which people are reminded: as if one had a friend named Horace and insisted on calling him Horsish because he had a new horse. There is the word "belfry," for example. In the beginning it had nothing at all to do with bells, and meant rather a shelter shed or a little tower; and it was spelled "berfry," after French "berfrei," from which it comes. But when the towers came

Photo by A. S. Burbank

Here are the Pilgrim Fathers on board the "Mayflower," sighting the shores of the New World. And what has that to do with stories from the dictionary? A very great deal, for that event and others like it filled volumes with dictionary stories. It meant a new crop of English words and meanings developed to fit a different life. It meant great shifts in the ways of pronouncing words in a whole branch of English speech. For whenever a group of people wanders away from the others who speak its language, it soon finds itself speaking differently. That is why "British English" and "American English" are rather different to-day, although, because we visit each other so often and because we read the same books, we can still understand each other easily enough. In olden days America would doubtless have developed a new language.

to be places for bells to be hung, people quietly changed the word to belfry because it reminded them of bells.

Many other words have been changed in this way. A primrose was at first a "primrole," but because both primroles and roses were flowers, and "role" looks a little like "rose," we now say "primrose." There was originally no "fish" in "crayfish"; the word comes from Old French "crevis." "Vis" really does not look a great deal like "fish"; but crayfish are water creatures, and so before long fishhood was thrust upon them. There is a long name for this process, it is called "folk etymology," and is used to describe new histories made up for words by people who do not know the real histories. It is an amusing and often very sensible sort of process.

Words That Become Lazy

Some words are lazy. Or rather, they have telltale stories which show how lazy most people like to be. These words began by meaning "now" and then gradually changed to mean "pretty soon," "sometime," "after a while."

Why Words for "Now" Wear Out

The present is now, is it not, and so "presently" should mean at this very moment? Yet if you say, "I'll come to that presently," you mean not now but in a little while. This word used to mean what it says, but it has grown indolent with its years. So has "directly." A schoolmaster in some old story will tell a pupil to "start directly," meaning "instantly"; to-day "start directly" might mean after a few moments have passed.

Of course when one "now" word turns shiftless or lazy, people have to find another one—for *some* things must be done on time! So words are always being taken into the language to mean "now" and then changing to mean "pretty soon"—for that is the kind of procrastinating creatures human beings

are. The old word "anon," which we run across so often in Shakespeare or the Bible, used to mean "instantly" but later got to meaning "soon"; then we did not need it any more, having so many "soon" words, and it has fallen into disuse. Even "by and by" used long ago to mean "at once."

A great many of us are never lazier than when we are talking. Whenever we like a thing we say it is "nice" or "grand," and whenever we do not like it we say it is "awful." As if "grand" could describe anything from a gorgeous sunset to a new candy bar! As if everything from a war to an unbecoming hat were "awful"—that is, worthy of being spoken of with fear and awe! Using so few of the words in our language when there are so many to use is rather like wearing always the same dress when one has a whole closetful of fine new ones locked up at home, all ready to be worn.

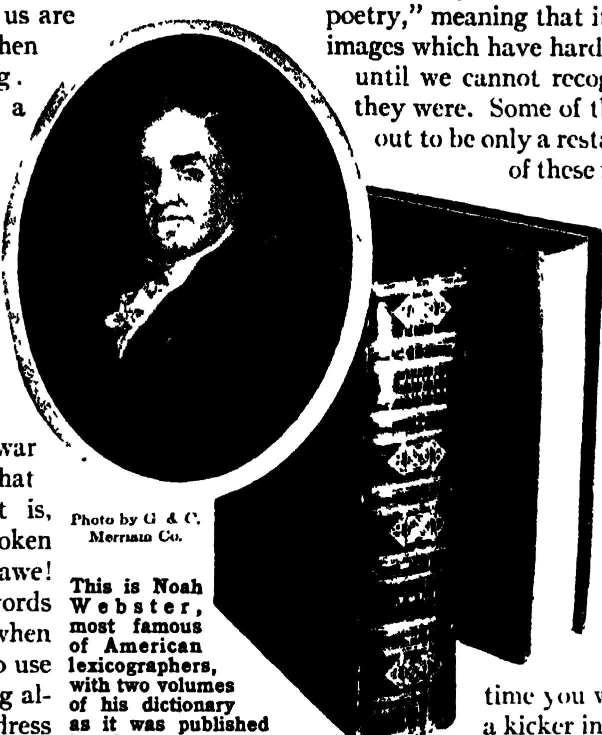


Photo by G. & C. Merriam Co.

This is Noah Webster, most famous of American lexicographers, with two volumes of his dictionary as it was published in 1828. Of course, it has been edited many times since.

Sometimes rubber-stamp expressions like these become very popular for a time, only to be forgotten in favor of the next set of rubber-stamp expressions—all alike showing that we are simply too lazy to pick and choose. This is one sort of slang. It is bad because it does not do what language is made for doing—it does not express our ideas.

The Test of Slang

But of course not all slang is bad. There are plenty of vivid and useful expressions in English to-day which once were slang, and no doubt some of to-day's slang will prove itself worthy to become good English too. The test is this: is there any way of saying this thing in accepted English? If so, is the new way more exact, more vivid, more useful? If there is no other way of saying a thing, the new way may very well fill a long-felt need. If the new way is better anyway, who would wish to cling to the old? Only we have to be very sure of our taste before we set up to judge of these things.

Somebody has said that "language is fossil poetry," meaning that it is full of bold, vivid images which have hardened like fossil bones until we cannot recognize them for what they were. Some of the better slang turns out to be only a restating in clearer words of these fine faded old images.

For instance, did you know that "insult" and "jump on" mean practically the same thing? The Latin word from which "insult" comes means "jump"; so to insult a person is really to jump on him. The high-sounding word "recalcitrant" originally meant "kicking"; so the next time you want to call a person a kicker in the politest of manners, you know what you can say. Also, to "impose on" a person is exactly the same as "putting something over on" him, since it comes from Latin "in," meaning "on," plus the word meaning "put." And "apprehend" is literally "catch on." Much of our good language is slang turned respectable.

There is a third sort of slang, the special talk of people in a certain trade. Prize fighters talk of "taking the count," "down and out," "side step," and these things have become slang among other people too. Card players speak of "a new deal," "placing all one's cards on the table," "something up one's sleeve," and "passing the buck"; and all but the last of these expressions have nearly completed their climb up through the regions of slang to those of proper speech.

It is rather hard to know just what to do about slang. Some sorts are altogether bad,

as we have said. Other sorts are not so bad. Of course we use much more rigidly proper words when we are speaking formally or writing than when we are chatting with our friends. But even with them we do not want to be either lazy or vulgar. It is a good thing to use slang sparingly, like salt in food, and go slowly about adopting any one phrase or word that we cannot find in the dictionary. The old motto is not a bad one:

Be not the first by whom the new is tried,
Nor yet the last to lay the old aside.

But suppose we close with two more stories of words which tell us vivid things about the romantic past. The first of these is "beggar." Away back hundreds of years ago there was in France a group of holy men called the Beghards. These men asked for gifts of money or food, and they were very active and clever in obtaining such gifts. Clear over in England the Beghards came to be known as good gift getters.

Photo by Keystone View Co

This is Sir James Murray (1837–1915), who probably knew as much about words as any man who ever lived. His great life work was editing the vast "New English Dictionary," from which we can find out the pedigree of any word in English and its whole life history through the ages. The people who worked under Murray handled so much material to make this dictionary that we hear of one scholar's shipping over to them "some ton and three-quarters of materials" which he had collected!

Finally their very name came to be used in English to mean one who asks for something in charity. And the word was worn down by use to "beggar." Then, since this word "beggar" looked like a good many other English words made out of verbs—peddler, baker, joiner, and so on—finally people made a verb "beg" out of it. So instead of a beggar's being one who begs, to beg is really to act like a Beghard.

And in conclusion, there is the little word "sake." We end with it because we should like to think its history stands for something. We should like to let it stand for the great change that has come over the English-speaking peoples during the centuries that English has been spoken.

When the English, or Angles, with their cousins the Saxons and Jutes, poured into England to conquer it some fifteen centuries ago, they were a fierce and warlike race. They loved fighting above all things. To them war was "battle-play." Their usual clothing was armor. They had so many words meaning "war" or "battle" that we cannot nowadays tell the difference among them.

One of their many words for war was "sacu." Most of the other war words disappeared from English, as men became more peaceable and thought somewhat less of killing one another. "Sacu" remained. But its meaning changed. It came to mean "interest" or "consideration"; so that when we do something for friendship's sake, or for the sake of a loved one, we are acting from the very highest ideals, far removed from those notions of war and bloodshed with which this word began.

What will "sake" mean in another thousand years?

And what will a good many English words mean in even a hundred years? No one knows. We only know that if English is to live, it must constantly change to fit new needs.

COMMUNICATION

Reading Unit
No. 4

OLD, OLD WAYS OF TELLING THE NEWS

Note For basic information not found on this page, consult the general Index, Vol 15

For statistical and current facts, consult the Richards Year Book Index

Interesting Facts Explained

Signal fires, 10 28-29
Messages carried by runners 10 30-31
Beating messages on drums and hollow logs, 10–29-30
The Inca cord messages, 10 30
Roman roads, 10–31-32
Carrier pigeons, 10 32
Animal talk, 10 27-28
How men communicated their ideas to one another before they learned to speak, 10 27-28

Things to Think About

Name some of the great events in history that have been told of by beacon fires
How were runners able to relay news 150 miles in one day?
Why did the Romans develop their good communication system?
How did criers send news across a country?

Related Material

How did the Indians kindle fires? 10–330-31
What means of communication did all the Indian tribes use? 7–108
How did the Indians record important events? 10 36
How is the carrier pigeon's sense of direction useful to man? 4–13
What methods did the ancients use to guide ships and sailors in the dark and storm? 5 181 186 187, 10–226
How did the Assyrians send messages to one another? 5 92

Practical Applications

Why were the Romans road builders? 10–32
How do primitive peoples talk to one another? 10–28-30

Leisure-time Activities

PROJECT NO 1: Make a model lighthouse, 14–34
PROJECT NO 2 Send a message to one of your friends by means of lights

Summary Statement

Ancient systems of communication were used only for official messages and important public news Unlike modern systems, they did not serve to carry private messages or to spread ideas.

"We want our dinner!" No need of words much less of newspapers to communicate this news! The human baby lets us know his needs in exactly the same way. The method works very well so long as we have only the simplest things to say and the people to whom we want to say them are within hearing of our cries.

OLD, OLD WAYS *of* TELLING *the* NEWS

When There Was No Newspaper, No Post Office, and Not Even Any Way of Writing, News Was Spread, Nevertheless, in Many Interesting Ways

DID you ever stop to think that we all spend our lives in a sort of prison? We never can step out of it, even for the briefest instant from the moment when, as tiny struggling mites, we enter the world, until we quit it as hoary men and women. It is not a very large prison either—some eight or nine inches at its widest. It is our skull; and our minds live inside it as long as we live. Its only windows are two tiny round holes that we call our eyes. But through those windows our minds can look out at the world around us; and in certain other ways we can find out what is going on outside our bony cells. We can hear, touch, taste, and smell things. In fact, we have so many ways of learning what things outside of us are like that it seldom occurs to us that we are in a prison at all. Because we can carry our prison about with us we hardly know we are in it.

But in it we are! And all our talk and gestures and writing are just ways of making signs to the world through its walls. They are pretty good ways, on the whole, but they are not perfect; so the long history of our race is in large part a history of our constant struggle to find out more and more perfect ways to make ourselves understood through our prison walls.

And now we are going to talk about a great many of the ways that early men invented to tell one another what they had to say, and to spread the news around the country. Long, long ago they began it all by just yelling; now we have the newspaper and the telephone and the radio, with many other things. But first we must see what ways they had to start with.

Have You Ever Heard an Animal Talk?

The animals did a great deal to help them. They worked out all sorts of neat little ways for telling each other about important matters. Have you ever heard a startled crow or blue jay warn the whole flock? Have you ever heard a mother cat give a little crooning talk to call her kittens—or a lusty robin calling to his mate from the peak of some gable on an evening in spring? The best orator cannot make himself understood a bit more clearly than they. And it was prob-

ably in some such way that the men who first appeared upon the earth communicated to one another the few ideas that they had.

But they soon came to have a great many more ideas than the animals had ever had, and then a mere cry or a gesture was not enough. There had to be a great many cries and gestures, and each one had to say a pretty definite thing. So complicated sign languages grew up, and complicated sets of sounds. And gradually, as men had more and more things to say, they worked out more and more perfect ways of saying them, until at last their cries grew into speech, or language. And the growth of language is still going on to this day.

Now when men had learned to talk to one another they had gone a long way toward breaking through their prison walls. As long as they were within earshot of one another they could say just about everything they needed to say. But if they wanted to tell something to a man a mile away, they had either to go themselves or send a man to go and say it for them. It was very slow and inconvenient. Imagine what would happen to all our modern life if suddenly it should come to pass that our only means of communicating with one another was by word of mouth. We should soon find ourselves mere savages again.

Photo by American Museum of Natural History

These savage cave men have gone far beyond the kittens who cry for their dinner. They have probably learned to speak a simple language. Besides, they have discovered the secret of striking fire from flint, and with fire they will be able not only to warm themselves but to send signals from hilltop to hilltop telling the tribe news of hunting or of war.

But after a while men found out ways to get around the difficulty. In our story of writing we have told how by slow degrees they learned to put their thoughts into some more lasting form than words. And even before that day they had hit upon various schemes for spreading news rapidly. Sometimes they could send an alarm through a whole tribe or nation in an amazingly short time. A fire lit on a hilltop would set a series of signals blazing almost instantly on every hilltop in the land, and within an hour or less the whole clan would be together in arms.

Some of the great events in history have been told by beacon fires. Faster than even the fleetest Greek ship could carry the news, flames springing up from hilltop to hilltop told Queen Clytemnestra that her lord and master, King Agamemnon, had taken Troy. And when the Scotch and the English were at each other's throats in the fifteenth century, an act of the Scottish parliament provided that "one bale of faggots shall be notice of the approach of the English in any manner; two bales that they are *coming indeed;* and four bales blazing beside each other to say that they are *coming in earnest.*"

In 1588 the hilltops along the English coast were ablaze with warnings of the dread approach of the Spanish Armada.

"From Eddystone to Berwick bounds, from Lynn to Milford Bay,
That time of slumber was as bright and busy as the day;
For swift to east and swift to west the ghastly war-flame spread,
High on St. Michael's Mount it shone: it shone on Beachy Head.
Far on the deep the Spaniard saw, along each southern shire,
Cape beyond cape, in endless range, those twinkling points of fire."

And if the fire could say a great deal, the smoke could say still more. The Picts in northern Britain, over beyond the wall that the Romans had built to keep them out, used to send up smoke signals to give one another the news. "Puff! Double puff! Double puff! Puff!" they would go. And while the Roman conquerors were still wondering what on earth those queer columns of smoke might mean, the Picts would be over the wall and fighting them tooth and nail. It was smoke signals that spread the news among the Indian tribes when the white man came to America. And to this day, the blacks of Australia, one of the most primitive of all peoples, are still using that old, old method for spreading news.

Somewhere far off over the plains other Blackfoot Indians will see the thin column of smoke from this fire and will be able to read its meaning. Perhaps the tribe is setting off to-morrow for new hunting grounds; perhaps the Crows are on the warpath; perhaps a new caravan of covered wagons full of palefaces is winding nearer across the plains.

Another way of sending news rapidly in ancient times was by shouting it from man to man. Caesar found a system like this working in Gaul. Whenever an important piece of news was expected, men were set on hilltops to give tongue as soon as they got word of the event. From hilltop to hilltop the message traveled fast across the miles in a language that was strange to the great Roman general and his men. Down in Peru, in the sixteenth century, Pizarro found wooden towers on the mountain tops to shelter the criers of news.

Sending Messages with Drums

And still another way of communicating was by drum taps. "Tom-tom-tom, tom, tom, *tom*" would go the drums in one village. The next village would hear the beats and pass them on to the third, and so the news would travel quickly through a whole tribe. Tribesmen of Africa and islanders of the Pacific still use this tom-tom telegraph, and it suits their simple purposes very well indeed. Some of them, too, send messages by means of blows on hollowed logs, and down in Malaysia news even travels by certain tunes played on the native instruments. Of course only the natives know the meanings of the strange sounds.

Photo by American Museum of Natural History

Those of you who have read that good old story called "Tom Brown's School-Days" will remember the sarsen stones, or "blowing stones," those strange hollow rocks on which a skillful blower could rouse a strange, weird blast that would ring through all the English countryside. No one knows for how many centuries the stones had been used for spreading an alarm.

Of course from early times runners had carried messages, both written and by word of mouth. Sometimes a picture on a bit of bark or wood or bone was all they needed to take with them to tell their story. To this day the Australian natives send messages on a certain kind of stick. A saw-toothed design on the stick may convey a cordial invitation to go on an emu hunt, while an interesting crisscross may announce a wellaby hunt.

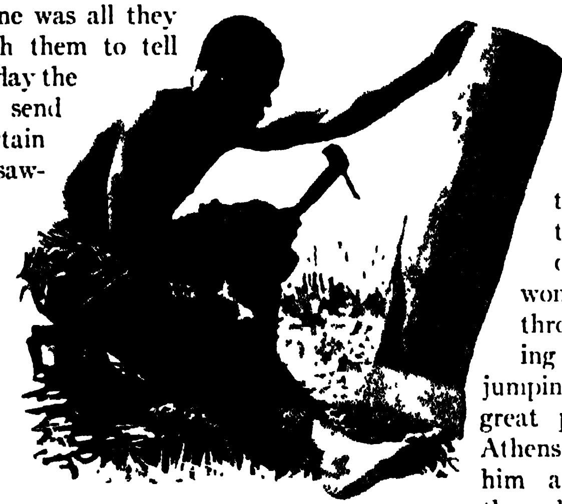


Photo by Field Museum

Here is a native of West Africa carving out a drum. While his people are very fond of music, it is as a means of signaling that their drums are famous. Even to-day news flies through the African bush so swiftly and mysteriously that the white men, who would be lost without newspapers and telegraphs, can only admire and wonder.

The news that Cortes had landed on Mexican soil went swiftly ahead of him up to the Aztec capital, borne by fleet runners trained in the service of the Indian emperor until they could make as good time as a horse. Each runner covered a stage of five miles, and then passed the message on to the next runner. In this way news could be relayed a hundred and fifty miles in a day. The Incas of Peru had much the same system. Over their fine roads the runners carried code messages made in string—one main cord with other cords of different lengths and colors and a variety of different knots to tell the messages. Thus they had a secret code that the Spanish conquerors could not understand.

The most famous runner in all history was Pheidippides (fī-dĭp'ĭ-dēz), a hero of ancient Greece. Foot messengers were very important in his country, especially during the Persian invasion, for over the steep and rocky trails that had to serve as roads, a man could go more swiftly than a horse. So fleet and strong runners were of the greatest importance for carrying messages from one Greek city to another.

Pheidippides had been a fine athlete from the age of twelve. At eighteen he entered the Olympic games as a citizen of Athens. Those were great athletic contests held every four years and attended by contestants chosen from all over Greece; and to come out a winner in one of the events and be crowned with the famous laurel wreath was enough honor to last a man for a lifetime. Imagine, then, the excitement on the day when Pheidippides won all five contests - throwing the javelin, hurling the discus, running, jumping, and wrestling. A great procession formed in Athens to go out and meet him as he was returning through the city gates. The rulers voted him a house and grounds, and he was given the right to choose the fairest maid of Athens for his bride. Three years later he became the "chief runner" for his city.

When the Athenians learned that Darius of Persia was again planning to descend upon Athens with his hosts, Pheidippides was sent to Sparta to ask for help against the barbarian invaders. Sparta was a hundred and forty miles away, but at the end of the second day Pheidippides was standing in the Spartan assembly saying, "Men of Sparta, the Athenians beseech you to hurry to their aid." Two days later he was back at home with the news that the Spartans would send reinforcements in five days.

Brave Pheidippides

But meantime the proud Persian army had already landed on the plain of Marathon, only twenty-six miles from Athens. There

Pheidippides had run 280 miles in four days, from Athens to Sparta and back again Then without taking rest he had gone to Marathon to carry messages and fight with his battling countrymen Now he has dashed back with the news of glorious victory, and at last sees the white pillars of Athens gleaming in the distance. But as he cries out the tidings to those who have come to meet him, he falls dead at their feet This brave Greek is the most famous of all couriers, but many others are famous too—one of them is our own Paul Revere, who galloped through the night before the Battle of Lexington

was no choice for the Athenians except to meet the Persians in battle at once So the little Greek army, only ten thousand strong, set out one hot September day in 490 B.C., and with them went Pheidippides Through all that day of carnage he carried messages back and forth through the army Then when victory was certain, he set out spent though he was, to carry the news to Athens

At sundown the watchers on the city walls saw him coming, no longer the swift Pheidippides but a man who staggered in his tracks They ran down to meet him at the gate, and as he fell into their arms they cried "What news what news Pheidippides?"

Blind and reeling, he feebly raised one arm and whispered hoarsely, "Victory is ours! Athens is saved!"

Then he fell dead

The news of Darius' defeat must have spread through his own empire pretty speedily, for he had gone far ahead of the Greeks in perfecting his organization for keeping in touch with all parts of his great domain At regular intervals along all the main routes were stationed houses and horses for the use of the messengers They rode night and day carrying the king's decrees and the reports of his officials—scratched on blades of bronze or graven on tiles or tablets of clay

When All Roads Led to Rome

But better still was the system of the Romans, the greatest organizers of the ancient world Five trunk lines of magnificent roads bound the empire together—and all of them led to Rome One went through Capua to Naples, and then across Sicily to Carthage Another stretched out into Macedonia by way of Brindisi (brēn'dē-zē) and the Adriatic A third went over to Constantinople then known as Byzantium (bĭ-zăn'shĭ-ŭm) and from there on into Asia A fourth extended into Spain And the fifth ran along the route that Julius Caesar followed in his conquests, from Rome to Milan and thence over the Alps to Germany, Gaul, and the north

Along those great highways were relay houses, with food and fresh horses—sometimes as many as forty—and excellent accommodations for the government riders. At some of the posts were carrier pigeons which messengers might take with them into a hostile country and send back with notes in case of need. Wherever the routes crossed the seas, a line of boats, with strong rowers, waited to carry the couriers swiftly on their way. Death was the penalty for interfering with a courier on his official duty.

A Roman messenger always wore a special badge of bronze shaped like a shield, and he carried his messages in a leather bag at his side. Sometimes they were written on scrolls of papyrus (pȧ-pī′rŭs), the kind of paper the Egyptians had learned to make from reeds that grew along the Nile. But more often they were engraved with a sharp instrument on tablets made of wax spread over thin sheets of wood or bone. Then, if there was danger of the message falling into the wrong hands, the courier could erase the writing simply by smoothing over the wax.

But though the Roman roads were built for all time and are still in use to this day, the fine system of communication was wiped out when the Roman empire fell apart in the fifth century. At best it and other ancient systems had not been used for much except the exchange of official messages or important public news. They had never served to carry private messages or to spread ideas. That remained for later centuries to accomplish, until, with the aid of modern invention, the great fabric of our modern system had been securely woven.

The old Roman gods, like the common mortals of their day, had to do without the telegraph; and they had no newspapers to read as they sipped their morning nectar. But they did have swift Mercury, with winged cap and heels, to carry their messages.

Reading Unit No. 5

HOW WE LEARNED TO PUT OUR MINDS ON PAPER

Note: For basic information not found on this page, consult the general Index, Vol. 15.

For statistical and current facts, consult the Richards Year Book Index.

Interesting Facts Explained

How picture writing began, 10-35-36
Picture writing and trade marks, 10-37
How Chinese writing grew from pictures, 10-37-38
How the alphabet was developed from pictures, 10-38-44
Hieroglyphics, 10-42
The Rosetta Stone, 10-41-43
The phonetic alphabet, 10-45

Things to Think About

How did our alphabet grow out of the Semitic alphabet?
Why did the Indian chiefs in North America use pictures when sending messages to their allies?
Why is it not possible to send messages in Chinese by telegraph?
What are the chief troubles with the English alphabet?

Related Material

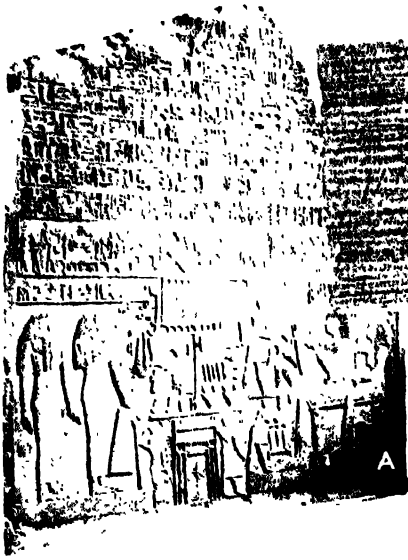
What is the oldest date in history? 10-477
How far did the Hebrew kingdoms of Judah and Israel extend? 5-48
When was Egypt the center of Greek culture? 5-181
Why did the Egyptian calendar work better than other early calendars? 5-49, 51, 10-477, 480
How did the Egyptians write numbers? 10-421-22
What was the main source of Roman culture? 5-218, 227, 229
When was Greek the international language? 5-181

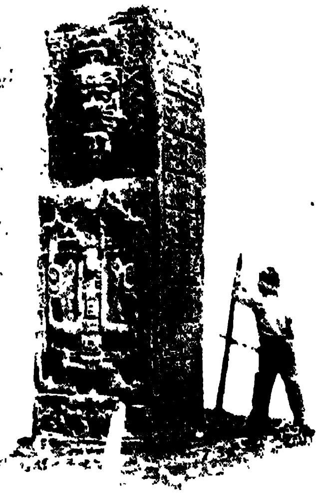
Practical Applications

How can a stenographer write words as fast as they are spoken? 10-45
Why is our alphabet of 26 letters able to do what it takes thousands of characters to do in Chinese? 10-37-44

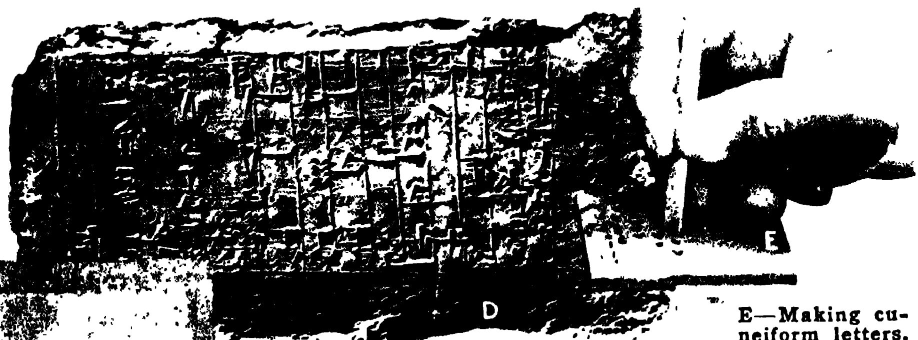
Summary Statement

The letters of the alphabet have changed almost beyond recognition from the old Semitic letter pictures out of which they grew. There are only a few letters which we still use in anything like their early form, and we now have more sounds than letters.



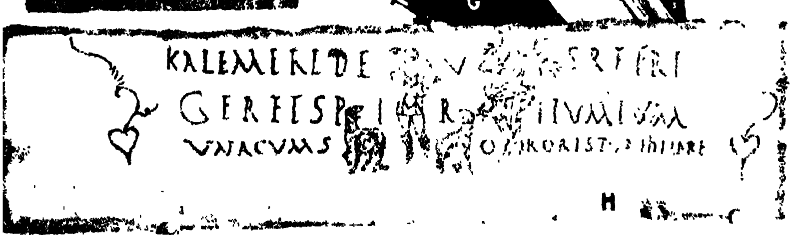


A—Egyptian wall inscription, more than 3,500 years old. B—Egyptian writing on papyrus. C—Mayan monument with inscriptions, Guatemala. D—Inscribed bricks from Ur, Abraham's birthplace.



E—Making cuneiform letters. F—Ancient wax tablet.

G—Monk writing in the Middle Ages. H—Early Christian inscription in Rome. I—Babylonian boundary stone.



For hundreds of years the monks were about the only men in our Western world who had any learning. In those dark ages even kings did not know how to read and write. And the monks were not only the scholars and physicians and scientists; they were the teachers too. And they were the "printers"! But they did not have presses to turn out thousands of books in a day. Every letter had to be made by hand, with a brush or pen. The pen was usually a quill, plucked from some goose or crow, and carefully cut to give it a good point. Quill pens were used as early as the first century after Christ, and for hundreds of years were the best instrument men had with which to write. Metal pens had been made in ancient times—one of bronze with a split nib was found in the ruins of Pompeii—and the "calamus," or reed pen with a split nib, had long been in use. But it was not till the nineteenth century that metal pens grew common.

HOW WE LEARNED *to* PUT OUR MINDS *on* PAPER

It Is a Curious Fact That Every Time You Write a Letter You Are Really Drawing a Few Hundred Pictures

OF COURSE people started talking long before they ever thought of writing. Even to-day there are savage tribes who have no way of sending messages except by word of mouth; but there are no people so savage that they cannot talk to one another. Writing probably began many thousands of years after talking started.

It grew first out of the fun of making pictures. Even when men lived in caves and the mammoth roamed the earth, people drew pictures. They traced them with sharp sticks in the sand. They smeared them with colored clays on flat stones. They even scratched them on bones or on soft rock such as sandstone.

In a region of France called the Dordogne are some of the very caves in which men lived ages ago, and on their walls are many drawings of the mammoth and of other animals, traced there by men of long ago who loved to make pictures just as we do.

Now of course such pictures are not really writing. If you drew a mammoth just for

fun you would be only drawing, not writing. You would not be telling anyone anything by your picture, except how the animal looks. But suppose you had the bright idea of drawing a mammoth, or a herd of mammoths, and sending it to some friend of yours to say, "There are lots of mammoths here; come and help me hunt." That would be writing.

Man's First Step in Writing

And that was probably the way writing started. Some man—or perhaps it was a boy or girl—who could draw pictures wanted to send a message. Perhaps he was going on a journey and wanted to leave word at the cave to say where he could be found or when he would get back. Perhaps he was in a strange country and wanted to tell a native something, but did not know the words. In either case, and in many other difficulties, pictures would be very useful.

Any picture that gives a message is writing—picture writing. It was one of the first ways of writing that man invented. The Indians of North America were great picture writers. An Indian could scratch a whole long letter on a little piece of bark. A sun would mean a day, a moon a month. A thing with a circle as head and a straight line for a body would mean a man; and there were other figures for money, for different kinds of food, and for other common articles.

As the Indians became more skillful picture writers they learned to express ideas by means of pictures, as well as to show objects. For example, a broken line might mean the path of life from childhood to old age; wavy lines might mean weakness or want of power. It is surprising how many things picture writing could express.

Picture Writing in America

And there was another great advantage in picture writing. It had nothing to do with speech. You know that if you draw a picture of a dog, anyone will know what it is, though you yourself may call it *dog* while the Frenchman says *chien*, the German *hund*, and the Russian calls it by a different name still. In just the same way, any Indian at all could understand a sun when he saw a picture of it, even though the person who drew the picture might belong to an entirely different tribe, and have quite a different word for "sun" from his own.

These pictures, then, were a speech everyone could understand. And they needed to be so, because the Indian tribes in North America spoke hundreds of different languages, and without these pic-

When men first tried to put their thoughts down in writing for other men to read, they could think of no better way of doing it than just to make pictures of what they were trying to say. The American Indians discovered how to write in this way, and could make a few marks on a piece of birch bark or skin say a great deal to anyone who knew how to interpret them. In the oval below is a sample of Indian picture writing. A means, Buffaloes came near the wigwams. B means, A humpback was killed. To-day we might have difficulty in recognizing the buffaloes, or might take the fatal arrow for an olive branch. But the Indians were more learned in these matters.

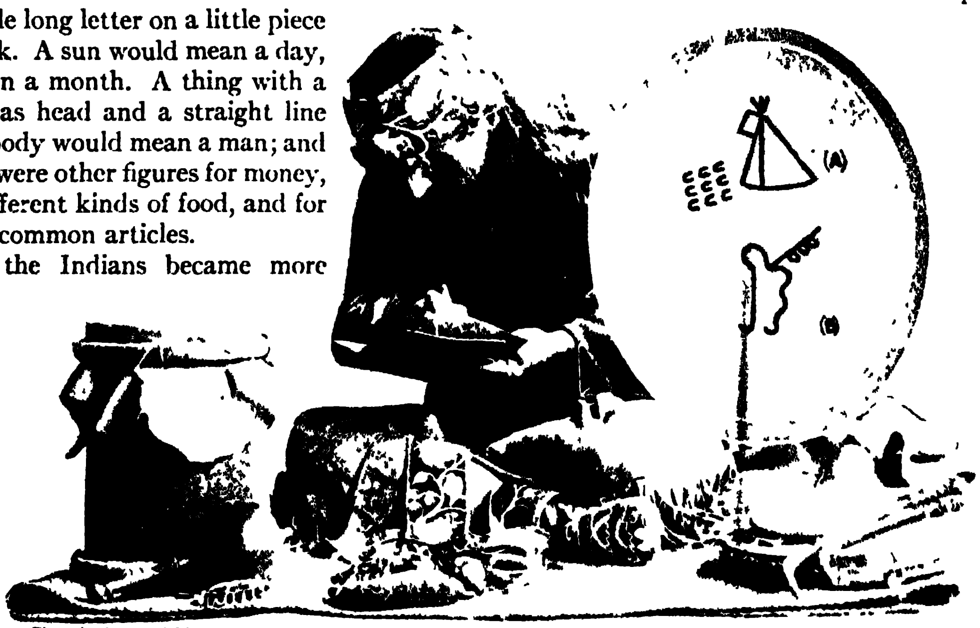


Photo by National Museum

tures a chief could not easily have sent messages to his allies telling them the things they needed to know. No other way of writing would have done so well as this one.

We still have picture writing in America, only we call the pictures by another name, we call them trade-marks. It is an interesting game to see how many common articles from the grocery you can guess from the picture you always see on the wrapper. All such trade-marks are examples of picture writing They say to you, "Here I am and I believe I am good, buy me"

Many thousands of these pictures are registered, or kept in the government buildings in Washington And if you send one there to be kept, no one else can use that picture It is yours But you can sell someone the right to use it, for it is thought to have a value Its value lies in its usefulness to advertise the thing it belongs with—the soap, tea, or cocoa that it always adorns.

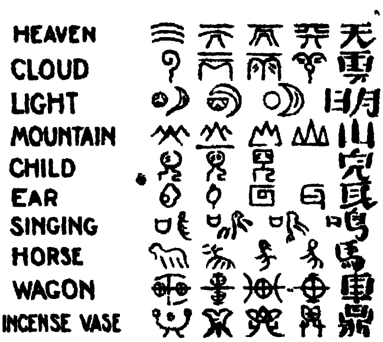
This Japanese bazaar is holding a sale, as advertised by the long ribbon of a sign at the right The Japanese took their writing from the Chinese, but instead of having a different sign for every word, they let a given sign represent a single syllable In this way the same sign could be used over and over again in different words, and writing was much simplified.

Phot by Presse Ill to Berlin

And besides this simple use of pictures for advertising messages, one of the great modern languages still uses the picture idea for its writing, although it is not a simple picture writing like trade-marks. This great language is the Chinese.

The Chinese, like the Indians, started their writing with pictures. Like the Indians, they soon began drawing pictures to mean ideas as well as things. And since the Chinese were much more thoughtful and clever than the Indians, their picture writing grew and grew until it became the biggest picture language the world has ever known.

In Chinese the signs used in writing are called ideographs, and were at first intended for pictures of the ideas they stood for. These pictures have been simplified until now they look very different from the thing they represent. But you can trace the history of some of them if you will examine the columns in the square. The ancient ideograms are shown in the first column, the modern form in the last column, and between the two the various steps are traced.



Imagine a dictionary in which every word was different from every other—not different just in the combination of letters, but different in all its parts A Chinese dictionary would be almost like that. Not quite, because there are a few pictures, standing for a few ideas, that enter into a number of words in Chinese For instance, the old picture for *house* had two up-and-down lines for walls and a line across for a straight roof, and that old picture for *house* is found as a part of several words, such as *to dwell, door, window*, and so on But a few such words do not help much

Chinese is so hard to write that it takes years and years to learn. You must be an artist in order to write Chinese well, and then, too, you must have a prodigious memory to recall all the funny figures, which are all that is now left of the pictures that meant words in the beginning. Every figure means a word, and every figure—thousands upon thousands of them—is different from all the

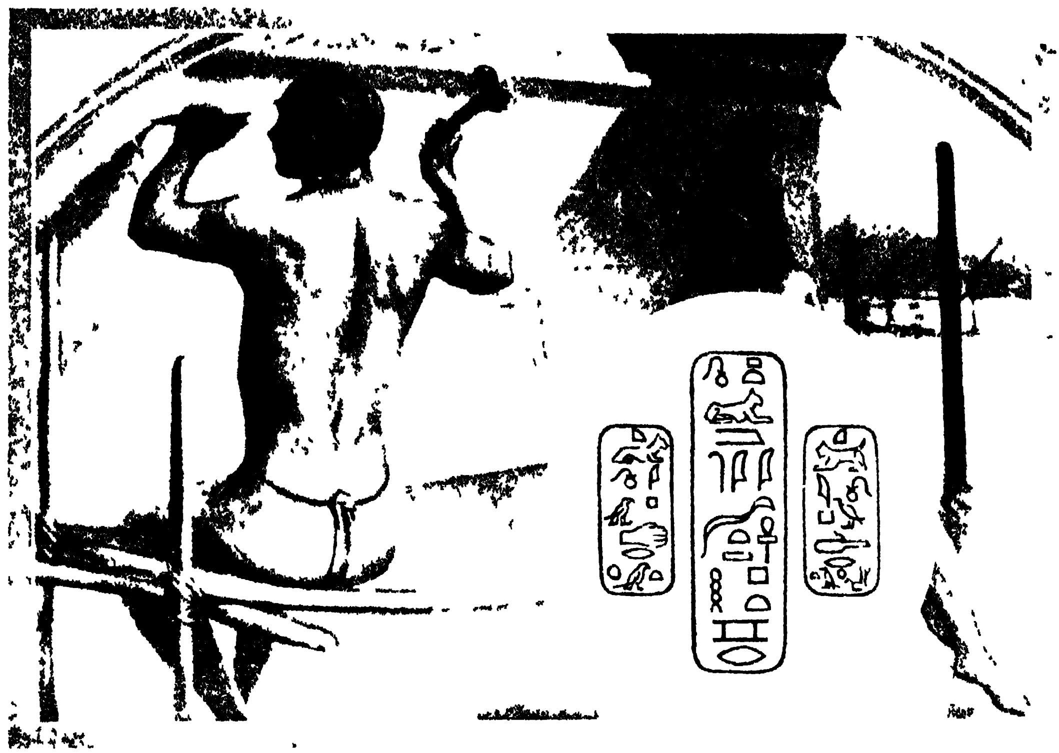


Photo by Gramstorff Bros

It was the Egyptians who first had the bright idea of letting a picture represent a sound instead of an idea. That was a tremendous step in the history of writing. Its final result was the alphabet. But the Egyptians did not invent an alphabet all at once. They made elaborate pictures to represent their sounds. In the scene above, the carver is cutting those pictures, or hieroglyphics, into solid stone, for scholars to read to-day. The oval shows how the hieroglyphics looked. In it are three cartouches (kar-toosh') that is, three ovals inclosing hieroglyphs that represent the name of a monarch. The two smaller cartouches belonged to Cleopatra, the famous Egyptian queen If you will compare them you will see that the characters represent the same objects, and therefore the same sounds. In the center is the cartouche of King Ptolemy V.

others. No wonder the Chinese have a hard time learning to write!

Telegraphing a Message in China

But that is not their only difficulty A language of this sort cannot be sent by telegraph. As you know, in telegraphing a language one combination of quick and slow clicks means *a*, another *b*, and so on That works very well when only about fifty such combinations are needed. But imagine trying to make separate combinations of short and long clicks for fifty thousand different words, and you will see another reason why picture writing bothers the Chinese. The pictures are such a nuisance that the Chinese are beginning to use a simplified set of words, with only about a thousand different figures, for their books. Perhaps sometime they will go further and begin to use the alphabet we use, with only twenty-six different figures; they already have to use such an alphabet to send their telegrams.

So picture writing, well as it served the Indians, is not much good in the modern world of dictionaries and telegraphs. It is very fortunate for us that alphabets were invented, for without them modern life would be much more complicated than it is.

How the Alphabet Was Invented

But alphabets did not just come into being by themselves. They were developed little by little out of pictures. And the idea that made them possible—the second really great idea in writing—was a tremendous event in man's history. The first great writing idea was to make a picture tell somebody something. The second was to make a picture stand for a sound, rather than a thing. This

In Central Park, New York City, is the Egyptian obelisk shown here in the center of the page. Those tall fingers of stone were set up along the ancient Nile in order that kings might leave upon them a record of their deeds for generations yet to come. The carvings on two faces of the obelisk are shown at the sides of the page. You will notice that you can make out various cartouches—that is, hieroglyphics set inside an inclosing line to represent the name of a person. Writing of this kind was very laborious to make, but as you may see, it was often very decorative.

second great idea, one which the Chinese and the Indians never hit upon, is called the "acrophonic" (ăk'rō-fŏn'ĭk) principle, or the use of the picture to represent the first sound in a word, instead of the whole word.

Suppose you were planning to send a letter in picture writing. Perhaps you can pretend you were the official sender of messages for a settlement in old Egypt, thousands of years ago. But you are different from the other senders of messages. You are different because you are cleverer. You like to think up new ways of doing things

In your language we shall pretend that the word for water is *ma*. You have often sent messages containing this word *ma* You draw it by making a choppy zigzag line like this ~ ~~ ~ That means "waves," or "water" You like to draw this picture for *ma*, water It is easy to draw, and it carries its meaning easily.

Now when you say *ma* you notice that you shut your lips tight and then open them. And there are many words in your language that begin with this same lip-shutting sound. You notice this, and in your own mind you call all these words *ma*-words—water words.

One day you are drawing some very hard messages with words in

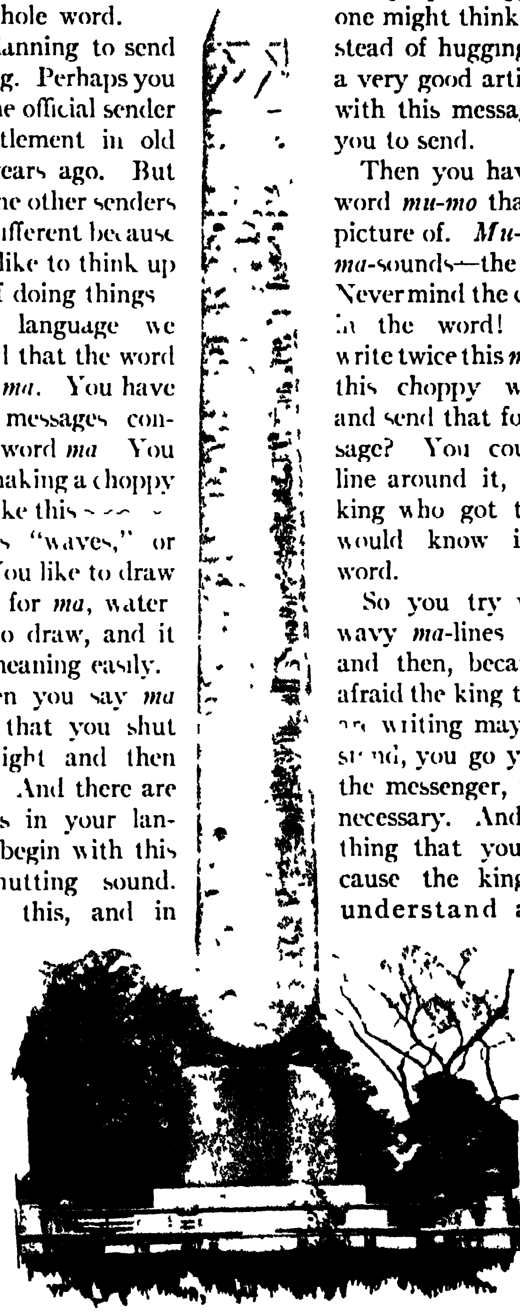
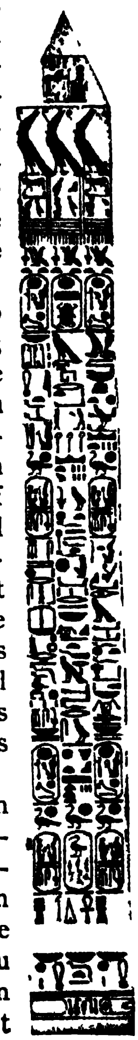


Photo by Keystone View Co

them that puzzle you, because you do not know just how to show them in pictures. How can you draw a picture of friendship, for instance? If you draw two people hugging each other, someone might think they were fighting, instead of hugging, because you are not a very good artist. You are disgusted with this message the chief has given you to send.

Then you have an idea. Here is a word *mu-mo* that you have to make a picture of. *Mu-mo* has in it two of the *ma*-sounds—the lip-shutting sounds. Never mind the other sounds in the word! Why not write twice this *ma* picture—this choppy wave line—and send that for your message? You could draw a line around it, so that the king who got the message would know it was one word.

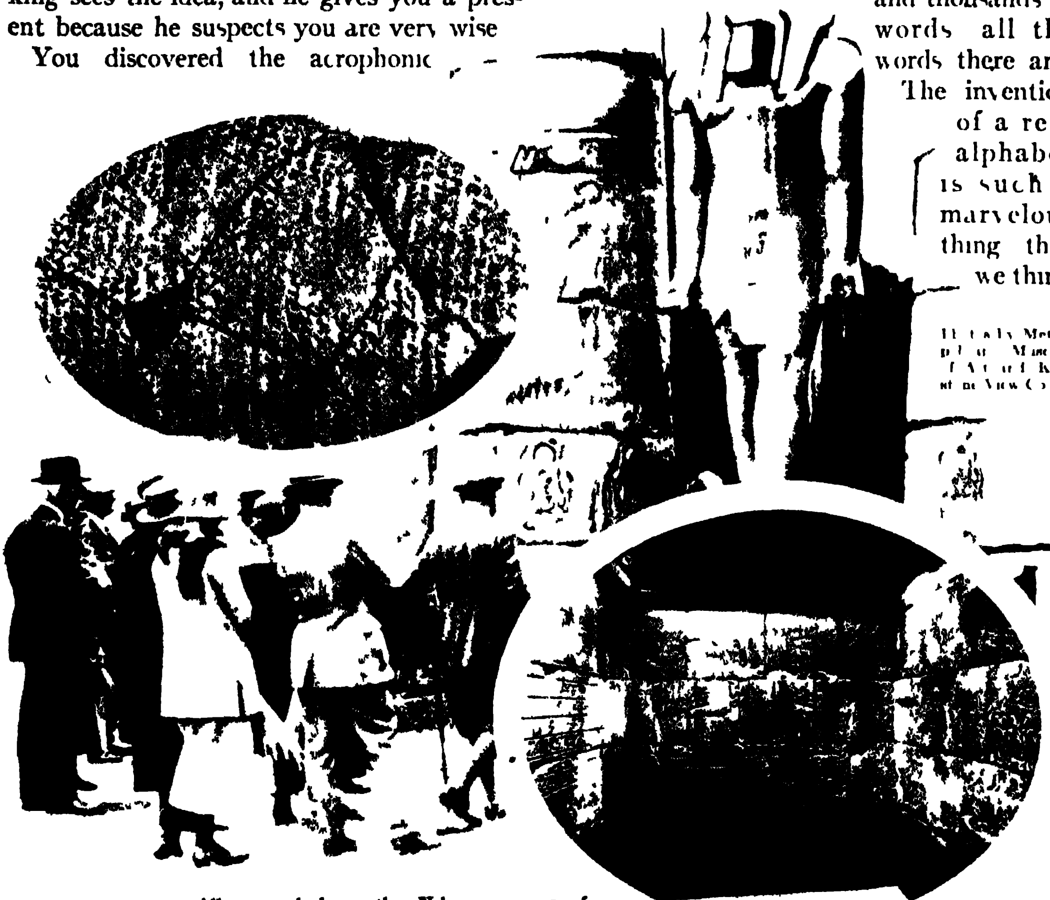


So you try writing two wavy *ma*-lines for *mu-mo*; and then, because you are afraid the king to whom you are writing may not understand, you go yourself with the messenger, to explain if necessary. And it is a good thing that you went, because the king does not understand at all. He just says *ma-ma* and wonders what it is all about.

So then you carefully explain to him that the picture you have drawn means, not

"water," but the lip-shutting sound After you have explained three or four times, the king sees the idea, and he gives you a present because he suspects you are very wise

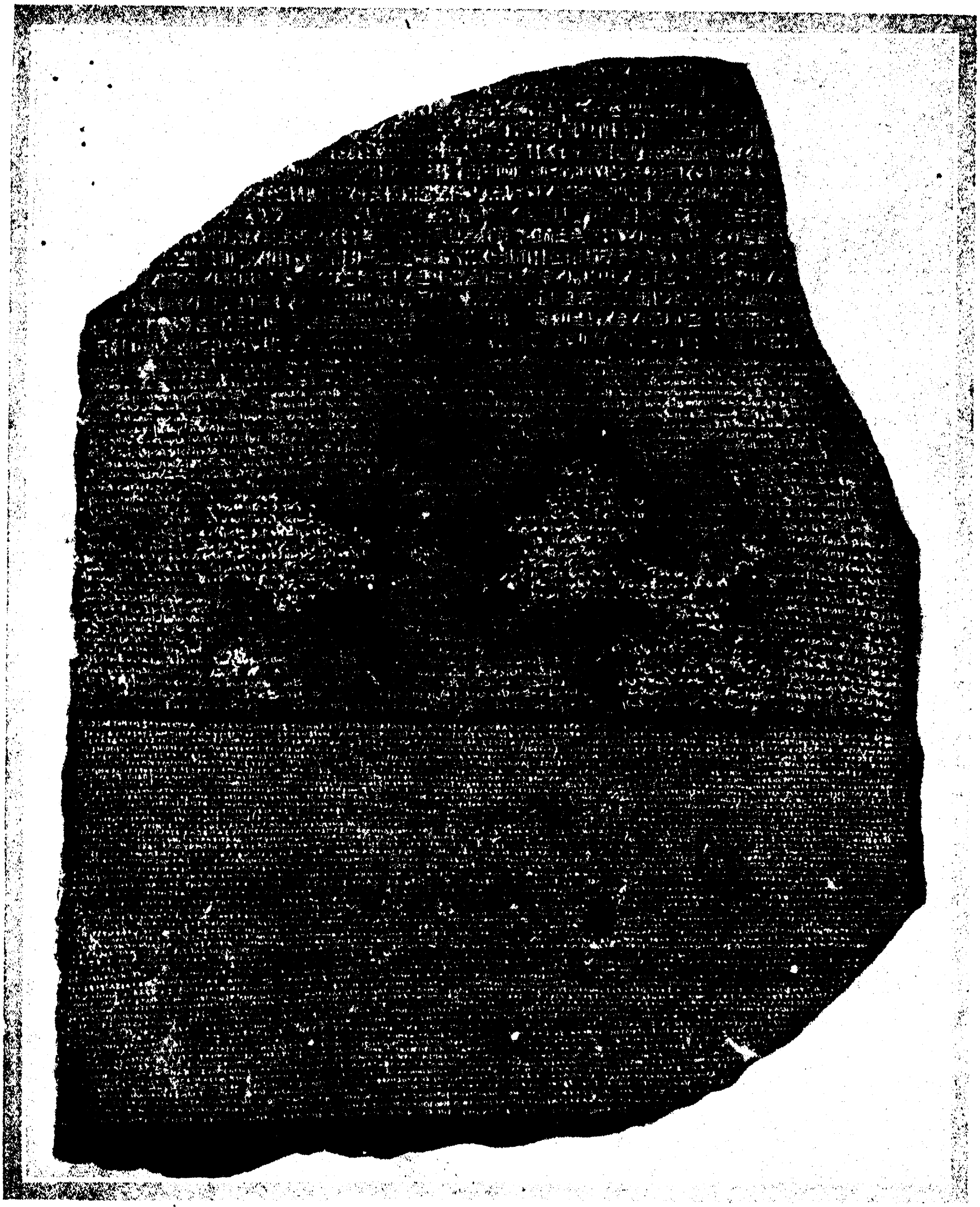
You discovered the acrophonic principle when you first used the *ma*-picture for the sound *m*. This picture you have taken for the first sound in the word which is the name of the picture You have made one of the greatest inventions of all time.



All up and down the Nile are ruins of tombs and temples left us by the Egyptians, and covering their walls are inscriptions in hieroglyphics that tell us of the lives of those men who lived so many hundreds of years ago. The center picture shows a famous event the opening of the tomb of King Tutankhamen near Luxor In the oval at the right is shown the interior of this ancient tomb, which has been transported to the New World and set up in the Metropolitan Museum in New York City. Its pieces are arranged precisely in the order that they were first set up in, thousands of years ago, and its inscriptions still bear, to those who can read them, the story that was carved there long before the New World, or the race that now inhabits it, had made its appearance in history. Often it takes great patience and cleverness to recover some of those inscriptions that time has dealt so roughly with. From the oval at the left you may see what a Chinese puzzle a scholar has to solve when he finds the stone all scattered and broken and must piece it together again before he can make out what it says.

Now consider how much time and bother you have saved yourself by inventing the *ma* sound picture. You will never again need to worry over how to draw pictures of difficult words like *mu-mo*. All you need to do is to make two wavy lines, with perhaps a couple of other pictures for *u* and *o*, and there you are With two or three dozen such sound pictures you can write thousands and thousands of words all the words there are! The invention of a real alphabet is such a marvelous thing that we think it could have happened only once The invention of word pictures was very easy as compared with that of pictures to stand for sounds We think that the very first alphabet was worked out in Egypt over six thousand years ago. And from its general idea—though not from its exact pictures—came all the various sound pictures in the world to-day.

The Egyptians did not really use a wavy line for *m*, although that sound picture was



Here is the picture of the most famous block of stone in the world. It was found in Egypt in 1799, and is called the Rosetta Stone, after a town in the Nile Delta near the spot where it was unearthed. The British Museum now owns it. It is of black basalt, and measures 3 feet, 9 inches by 2 feet, 4½ inches; it is 11 inches thick. But heavy as it is, its worth is many times its weight in gold, for it was by means of the Rosetta Stone that scholars were first able to decipher the Egyptian hieroglyphics, and so to learn the history of the strange land along the Nile. The inscription on the stone is written in two languages, Greek, at the bottom of the stone, and Egyptian. The Egyptian version is in two forms: at the top it is in the old hierglyphics, nearly always used for state and religious purposes, and in the center it is in the demotic characters, a simplified form of writing which had come into use for ordinary purposes by 196 B.C., the date of the stone. Because scholars already knew Greek and Coptic—the Egyptian language as spoken by early Egyptian Christians—they were able, after many years of study, to puzzle out the hieroglyphics. The inscription commemorates the coronation of King Ptolemy V, and tells of his great deeds.

a part of another early alphabet, the Semitic (sĕ-mĭt'ĭk). But the Egyptians did first draw sound pictures for their writing, and these pictures we now call hieroglyphics (hī'ẽr-ô-glĭf'ĭk) In these hieroglyphics there is a picture of a lion which, oddly enough, means L, the first letter in the Egyptian word for "lion" as well as in ours There is a picture of a large bird which means A. And there are many other such pictures

Even the Egyptian hieroglyphics proved rather awkward after a while. Imagine carefully drawing a lion every time you wanted to make L! The picture itself was too complicated for quick writing So, little by little, Egyptian scribes began to leave off parts of the picture—the feet, or even the head And in this way another sort of writing developed. In it you did not have to lift the pen or brush from the paper every time you wanted to begin a new letter, and pictures themselves were easier to draw. This easier, quicker writing is now called demotic (dē-mŏt'ĭk), from a Greek word meaning "people," for it was the writing used by ordinary people Hieroglyphics were still used in very official or dignified writing, but not for every day

For hundreds of years people saw this queer hieroglyphic writing without being able to read it The old Egyptians were all dead, and no one remembered what their writing meant We might never have found out, if there had not been discovered, in 1799, a flat black stone which has ever since been called the Rosetta (rō-zĕt'à) Stone, because it was found near a place on the Nile which the French call Rosetta On this stone the same words had been written first in hieroglyphics, second in the demotic writing, and third

On this large stone, now in the Museum of the Louvre, in Paris, is the earliest Phoenician writing to which we can assign a definite date. The inscription, which is doubly interesting to us because it clears up a passage in the Bible, tells how one Mesha, king of Moab, put down a rebellion nine hundred years before Christ. The Moabite Stone was discovered in 1868 near the Dead Sea, on the spot where the ancient capital of Moab once stood. But the Arabs, seeing that the strange affair was valued by the Christians, seized it and broke it to bits. Luckily impressions had been taken of the inscription, so that the stone could be partly restored, as you see it here.

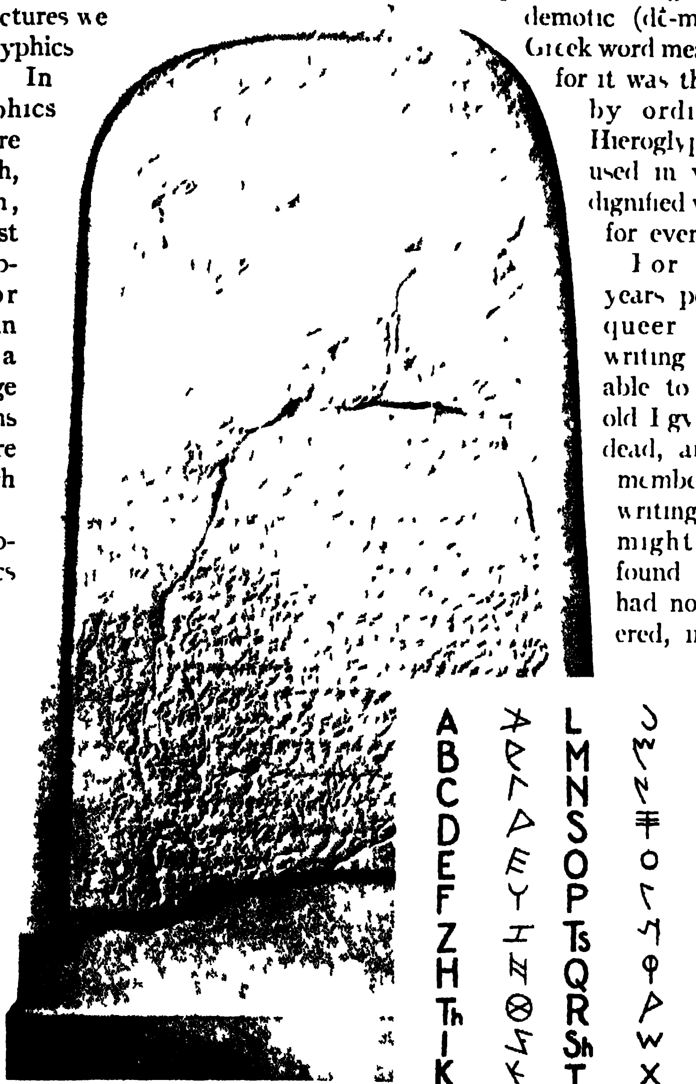


Photo by Metropolitan Museum of Art

The Phoenicians always wrote from right to left instead of from left to right, as we do; and their letters faced in the opposite direction from the one the Greeks showed them as facing toward. For when the Greeks borrowed the Phoenician alphabet, they wrote it from left to right, and turned the letters about. It was from those reversed Phoenician letters, which the Greeks adopted, that our modern alphabet descended. From the two sets of columns in the inset you may see how much the millions of hands that have used those letters through the ages have changed and shaped them into our alphabet to-day. The second and fourth columns give the Phoenician letters, but turned about, as the Greeks wrote them, the first and third columns give our modern equivalents.

Photo by Gramstorff Bros

Writing is an old, old art in China. The picture above shows how records were kept there many centuries ago. It was there that paper was first made, fashioned from a mixture of vegetable fibers.

in Greek, the language of the king of Egypt.

Now people had never forgotten how to read Greek, and so that part of the writing gave them the general meaning of the hieroglyphics. And they noticed also that certain hieroglyphic words had an oval line, which they called a cartouche (kär-to͞osh′), around them. They decided that these cartouches must contain the names of kings or queens. And by patiently figuring what king's name must be within the lines, they finally worked out the letters which the hieroglyphics stood for. Nowadays wise men can read hieroglyphics readily, and all because of the Rosetta Stone.

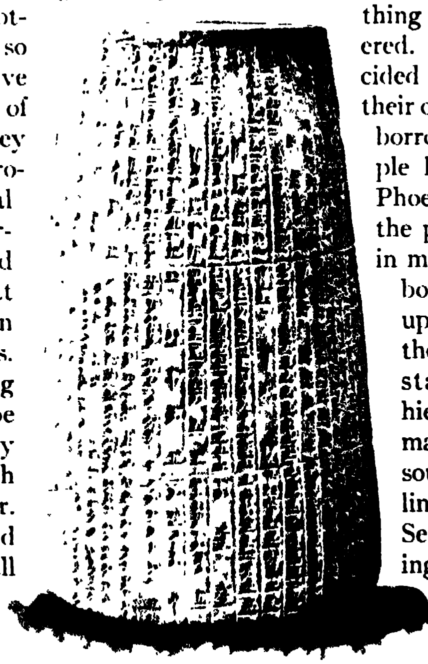


Photo by Deutschen Museum

When Nebuchadnezzar, king of Babylon, wished to tell the world of his great deeds he punched holes in soft clay and baked the record in an oven till the clay was hard as stone. Here is a cylinder bearing one of his inscriptions of 2,500 years ago.

These Egyptian hieroglyphics have precisely the same idea as our own English ABC's, but the form is very different. Where did the English letters come from?

Well, after the first alphabet was made, other people saw what a useful thing the Egyptians had discovered. And very soon they decided to make sound pictures of their own. Among these alphabet borrowers were the Semitic people living in Palestine and in Phoenicia (fê-nĭsh′ĭ-a). Since the picture idea was still fresh in men's minds, these alphabet borrowers decided to make up their own pictures for their own sounds. For instance, where Egyptian hieroglyphics have their own mark for *m*, the Old Semitic sound pictures had the wavy line which stood for the Semitic word *mayim*, meaning waters. In this Semitic sound picture we can clearly see our own letter *m*, which is a direct descendant of the water picture of the ancient Semites.

Both the Hebrews and the Phoenicians were Semitic people, and both of them borrowed the idea of the Egyptian alpha-

bet when they began to work out their own; but it was the Phoenicians and not the Hebrews from whom the Greeks got the alphabet which, somewhat changed, we use to-day. A very old story tells us that it was Cadmus, a Greek, who brought his people into Europe and who gave them their alphabet. Whether or not there ever was a Cadmus, it is certain that the Greeks got their alphabet from the Phoenicians.

By this time people had forgotten about the pictures which stood for the sounds, and only thought of the sounds themselves when they looked at the pictures. You see quick writing had changed these pictures so that they did not look very much like the thing they were supposed to represent. For example, the first letter, *aleph*, from which we get *a*, was supposed to be a picture of an ox. But when first we meet it, all you can see is two horns and a yoke across; and in later Semitic writing the picture was changed still more, so that when the Greeks got it, only the two horns are visible, and they are down at one side instead of up where they should be. So the Greeks did not need to bother to make up a new set of pictures; they just decided that a couple of horns could be the *a*-sound, and a wavy line the *m*-sound, without caring what these lines pictured. And we make a wavy line for *m* to this day!

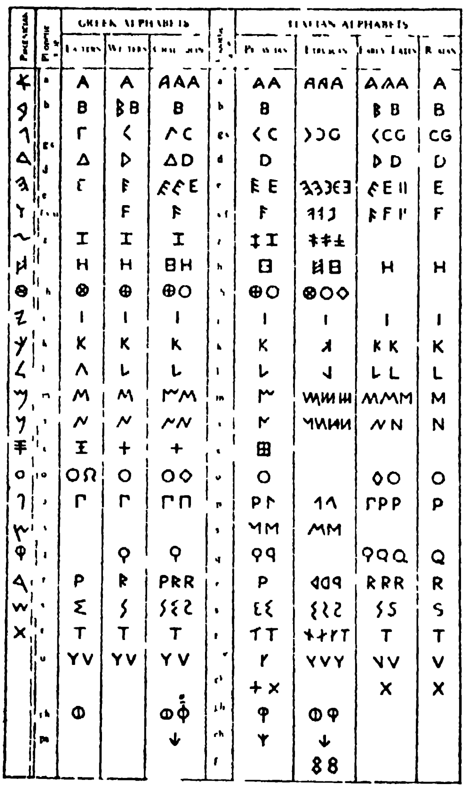


Photo reproduced from A History on the Art of Writing by Mason, Courtesy MacMillan Co.

Our modern simple alphabet was not built in a day. Its earliest ancestor first saw the light in ancient Egypt. There the Phoenicians got it, in a form very strange to our eyes, and passed it on to Greece and Italy. Its family tree is shown above, from the alphabet those Phoenician sailors used, down to the one fashioned by the practical Romans. It is hard to realize to-day that once upon a time the letter A was an eagle; D, the human hand; and M, an owl.

The Growth of an Alphabet

So in passing from the Phoenicians to the Greeks and from the Greeks to the Romans and from the Romans to the English, the old Semitic letter pictures got changed almost beyond recognition; there are only a few which we still use in anything like their early form. The letter *m* is one of these, and another very old sound picture is the letter T. Except for the fact that the head is gone, this letter still preserves very closely the old Egyptian "life sign" -- the picture of a man, with head, arms, and body.

The Egyptians at first drew their sound pictures on walls, or chiseled them into stone The Hebrews too used stone slabs for writing, although both they and the Egyptians later had a kind of paper called papyrus (pȧ-pī′-rŭs), made from the stems of a plant with the same name. The Assyrians and the Babylonians wrote in what is called cuneiform (kū-nē′ĭ-fôrm). They had a peculiar method of stamping wedge-shaped figures into wet clay bricks. The clay would harden into brick, and there would be a letter -perhaps an invitation to dine or a bill for a suit of clothes. The Romans liked to use wax tablets, on which they wrote with a pointed tool called a stylus (stī′lŭs).

Later still, the men who invented our own language, the Anglo-Saxons, cut out flat slabs of wood on which to write, and carved letters on them just as you might carve your name on a pencil. Two of our words, ***book*** and ***beech***, come down from these early days. A beech is a sort of tree that will carve easily, and ***book*** and ***beech*** were the very same word at first, because a book was nothing but a beech slab.

Many early books were rolls, written on

long wide ribbons of parchment and rolled on two round sticks, one at either end. This way of making books was much better than using stone slabs or clay bricks, because a book was lighter and easier to carry. But still our modern books are a great improvement, for we can turn to any page easily, while it must have taken a long time to turn to any given sentence in a book roll.

It seems odd to think that an alphabet might wear out and need to be replaced by a new one, but sometimes things do happen that way. Our English alphabet is just such a worn-out set of letters; and it might easily be argued that the people who speak English would profit by throwing their alphabet away, and getting a new one. In some ways our letters have been worn out for a long time, but some of the wear has begun more recently.

You will remember we said that when the message writer wanted to write *mu-mo*, he just wrote *mm* and left out the other two sounds? Well, that was the way of the two greatest early alphabets, the Egyptian and the Semitic. Only the stronger sounds, the consonants, were pictured. The weaker sounds, the vowels like *a*, *e*, *i*, *o*, and *u*—were left out.

When the Greeks and Latins got their alphabet, they made pictures for some of those weak vowel sounds, but they did not make enough of them. No one has ever succeeded in completing the list of vowel letters. And so in Modern English we have fifteen vowel sounds and only five letters to write them with. We now use the same letter for two very different sounds in *so* and *to*, and still the same letter in *won* and *hot*. That is one trouble with the English alphabet, but it is a very old one and goes back to the beginning of all the alphabets clear back to Egypt.

But English has other alphabet troubles that are all its own. In all, there are about forty sounds in English, but we have only twenty-six letters to picture these sounds, and of these twenty-six letters some could be lost without hurting the alphabet a bit. The letter *Q* is the same as *kw*. The letter *X* is always either *ks* or *gz*. The letter *c* is always either *k* or *s*. These letters *q*, *x*, and *c*, therefore, are really not needed in English.

Men who have studied language have made up an alphabet, called the alphabet of the International Phonetic Association, to express in a true and scientific way the sounds of English. It has one letter for every sound, and only one. Here is a poem in this phonetic (fō-nĕt′ĭk) alphabet. See if you can read it.

mɛrɪ hæd a lɪtl læm
ɪts fli:s wəz ʌaɪt əz sno:
ænd ɛvrɪʌɛɹ ðət mɛrɪ wɛnt
ðə læm wɔz ʃu:r tə go:

Perhaps this looks very difficult to you, but if you should once learn it, it would seem easier than the way you write now. For one thing, you would never again need to bother about spelling, because everything would be spelled just as it sounded. And since this is an international alphabet, you could pronounce French or German in it about as easily as you now pronounce English. Of course you could not understand what you read unless you knew French or German, but even to pronounce it would be useful.

One of the newest alphabets in use to-day is that of Russia. This way of writing was devised only about five hundred years ago, and it has not had time to get worn out. It has thirty-six letters, ten more than English, so every sound has a picture of its own.

Just as the Egyptians began leaving off parts of their complicated sound pictures, so men in modern times have looked for ways to make writing quicker. These quick ways of writing are called shorthand, and a number of different shorthand systems are in use to-day. Several of these systems leave out the vowels just as the old Egyptians did, except that they do have dots for the vowels, which can be put in if the writer wishes.

Shorthand uses single lines running in different directions, or small curves, or hooks, as its letters. It is based on sounds, not upon the alphabet. Some stenographers can write about as fast as a person can talk.

Reading Unit
No. 6

THE ROMANCE OF PRINTER'S INK

Note: For basic information not found on this page, consult the general Index, Vol. 15.

For statistical and current facts, consult the Richards Year Book Index.

Interesting Facts Explained

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How the art of printing spread through Europe, 10-51-54
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How are pictures and photographs printed?
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Picture Hunt

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Summary Statement

Although books are works of art, they are printed for our everyday use. Without them we could hardly have either popular education or democracy, which demands intelligent citizens.

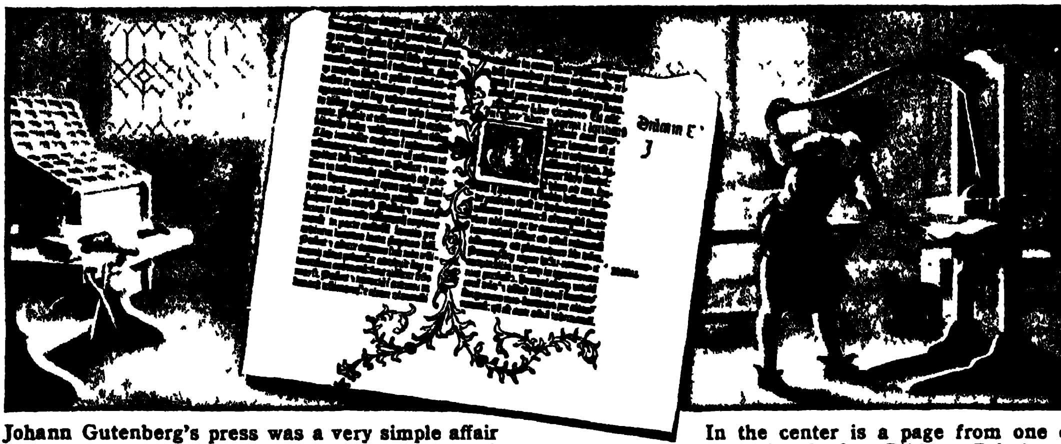
This devout group has gathered in St Paul's cathedral in London to listen to a reading of the Bible Books were rare treasures in those far-off days All homes were without Bibles, and church Bibles were chained to the walls, as this one is! And, of course, since there were few books, few people had learned how to read.

The ROMANCE *of* PRINTER'S INK

For Many a Weary Thousand Years Every Word That Was Written Had to Be Put Down by Hand. Then, Finally—Why Did It Come So Late? Some Man Thought of Using Type, and So Made the World Over

SUPPOSE that in all the world there were no scrap of printed matter—no newspapers, no magazines, no books, except a few handwritten volumes chained up in public buildings and the libraries of the very rich, no advertising cards in cars or subways, no signboards, no printed directions on medicine bottles and boxes of breakfast food, no little circulars sent through the mail to tell about the latest ways of planting crops or rearing babies, no mail-order catalogues, no—but why go on? The world as we know it has already melted away before our mind's eye, and we are trying to get our bearings in another world altogether.

In that world a man wishing to buy a big country house might pay for it with a single book if he had one. When Louis XI, king of France, wanted a certain book from the library of the University of Paris, the learned doctors shook their heads mistrustfully and would not let the precious volume go, even to the King, until a costly silver goblet had been deposited in its stead. In the fourteenth century all Europe contained fewer books than are in many a town library to-day.



Johann Gutenberg's press was a very simple affair compared with the great printing machines of to-day, but it was one of the marvels of the fifteenth century, and a great stride in the advancement of civilization.

In the center is a page from one of Gutenberg's first Bibles. Printing is an everyday affair to-day, but no modern book can equal this ancient text in beauty.

In that world, scarcely one person in five hundred could read or write. Why should they learn, when they would never own a book? Those who knew how to read were mostly in the service of the church. Patient monks sat month after month making a single copy of a single book. Often they formed the letters with loving care and illuminated the pages with scrolls and pictures and initial letters in lovely color. But it takes a long time to make a whole book by hand; and when you are through you have only one copy after all. A certain great book of church law took twenty-one months to copy; at that rate it would take nearly two thousand years to make a thousand copies. A big publishing house can now turn out a thousand books in less than an hour!

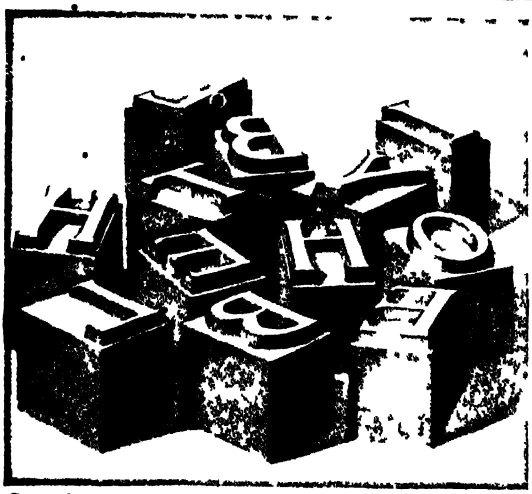
Who Invented Printing?

It is not at all certain just who invented printing, or when, or where. For centuries before the Europeans thought of it, the Chinese had known how to print. The earlier method was to carve letters in relief on a wooden block, ink them over, and then transfer them to paper by pressing the paper down hard on the inked block. The Chinese even printed from movable type as early as the eleventh century. But both processes seem to have been invented all over again in Europe. By the middle of the fourteenth century playing cards were being printed in Europe from blocks, and crude picture books —"block books"— were being made in the same way. Of course everything that was so printed had to have its own especial block.

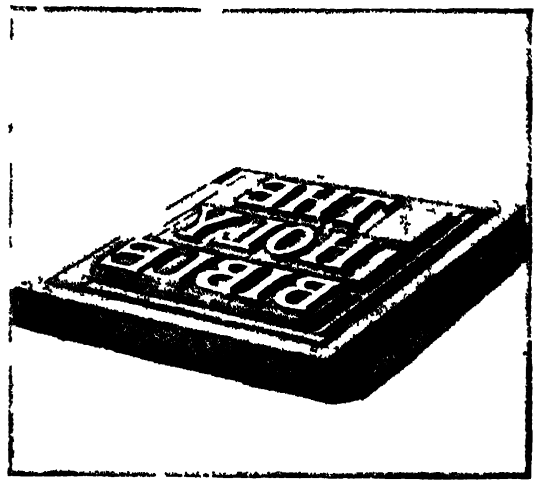
Who was the first man in Europe to think of making each letter in relief on a separate bit of metal, so that the letters could be arranged and rearranged at will—that is, who thought of printing with movable type? We do not certainly know. The Dutch claim that it was Laurence Coster, a Hollander, and the French and the Italians have their candidates, too. But the man with the best claim is Johann Gutenberg (gōō'tĕn-bĕrg), of the German city of Mainz (mints), where he had been born into a well-to-do family somewhere about the year 1398. The earliest bit of printing we have from his press is dated 1454. So this, one of the greatest of all inventions, came in the very midst of the period of mental excitement and upheaval which we call the Renaissance (rĕn'ĕ-sôNs'). And it was this invention which was to make the knowledge that the men of the Renaissance loved so much, available to all the people.

How the First Type Was Made

Gutenberg and his partners, Johann Fust (fōōst) and Peter Schoeffer (shûf'ĕr), kept their experiments a deep secret. Gutenberg seems to have started by carving his types out of separate blocks of wood. It was probably Schoeffer who suggested that, instead, each letter should be cut out of hard metal. This metal letter could then be used as a punch to make an impression in softer metal; the matrix (mā'trĭks), or mould, thus formed



Gutenberg must have used wooden blocks like these, although his letters did not have these modern shapes

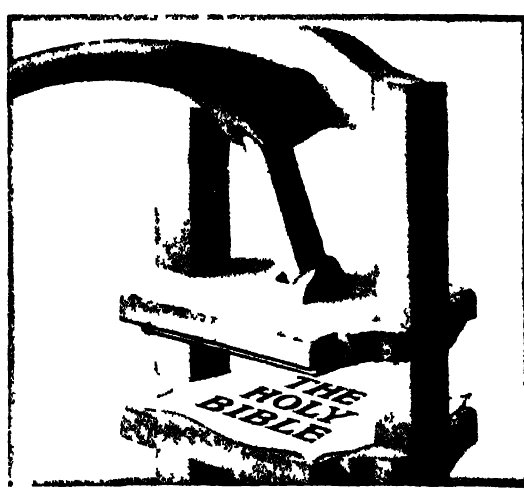


After the blocks had been arranged in the proper order, they must have been locked together like this

The next step was to spread ink over the raised surfaces Can you make out what the words will be?

The letters in their frame were then locked in the press and a sheet of paper was put underneath

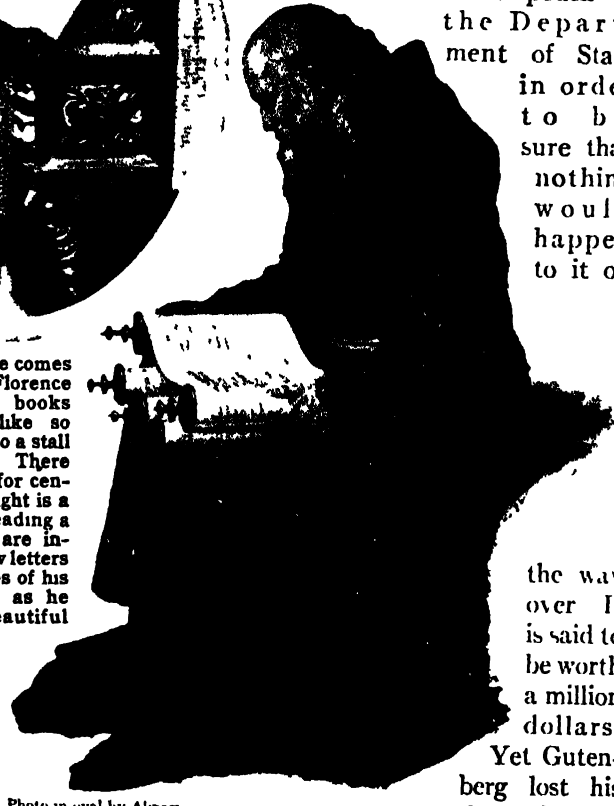
When the handle of the press was pulled down, the inked letters were pressed against the paper.



The happy printer could make any number of these pages. The days of tedious copying by hand were over!

could be filled with melted lead; and when the lead had hardened and cooled into the form of the letter, it could be taken out—a finished piece of movable type—and the matrix used again and again to mould more letters. So lead, one of the heaviest of metals, came to serve as wings for words and thoughts, and for the spread of knowledge.

It was Gutenberg's great ambition to print as his first whole book a copy of the Bible. This took a long time; for each letter had to be carefully drawn and cut into a hard metal punch, the moulds had to be made, the type had to be cast and set and inked over, and each page had to be printed on a hand press very like the presses for oil or wine common in many households of the Middle Ages. But, at that, the process was speed itself compared with the work of the hand copyists; for when Gutenberg—or whoever did the work—finally got through, he had not one volume but many to show for his pains. It must have looked like magic to the people of the day, for the printers did not tell anyone how they had done it, but tried to make every letter and illustration look as if it had been done by hand. As a matter of fact, Johann Fust himself, somewhat later in Paris, did actually have to give up his secret to satisfy the church authorities that he had not been dealing with the devil.



The picture above comes from a church in Florence where valuable books were chained, like so many prisoners, to a stall of carved wood. There they have stood for centuries. To the right is a Jewish scholar reading a scroll on which are inscribed in Hebrew letters the ancient stories of his people. As fast as he unwinds its beautiful pages from one roll, he winds them up again on the other. That was the common form for books to take in ancient times.

Photo in oval by Alman

Those first Bibles of Gutenberg's are among the most precious things in the world to-day. They first appeared in 1456, and only a few of them still exist, the three finest being in the British Museum, the Bibliothèque Nationale, or "national library," of France, and the Congressional Library at Washington. The last of these was discovered not many years ago in an old monastery far up in the Alps and sold to the United States government by Dr. Otto Volbehr, the discoverer. When he brought it from Austria, he had it locked in the diplomatic pouch of the Department of State in order to be sure that nothing would happen to it on the way over It is said to be worth a million dollars. Yet Gutenberg lost his share in the printing business and died a pensioner of the Archbishop of Mainz.

When you go to Washington, be sure to visit the second floor of the Congressional Library and look at the Gutenberg Bible in its glass case. It is opened so that you can see that it is printed on mellow old parchment that has stood the wear of the centuries. The printing is even and clear, but you would have a hard time reading it. For even if you can read Latin, the language in which it is

This painting shows you the workshop of Bernardo Cennini, a master goldsmith of fifteenth century Italy and the first man to set up a printing press and make metal type in Florence

printed the antique Gothic letters patterned after the hand lettering of the monks look intricate and strange But the hand drawn and illuminated initial letters, the scroll borders, and the little pictures, all done in clear and exquisite color, like jewels in a setting of gold, make the page a joy to look at And as you gaze at it, you must not forget that you are looking at one of the most important landmarks in the history of mankind

The Spread of the Art of Printing

A few years after Gutenberg's death there was an upheaval in Mainz the press was wrecked, and the printers fled from the city Wherever they went they spread the new art of printing It had already been carried into Italy by two Germans named Sweynheym and Pannartz, and a famous center of the art grew up at Venice There Nicholas Jensen, by birth a Frenchman, invented the Roman type in "lower case"—that is in small letters rather than capitals—which is still the basis of the designs for most modern printed letters, such as those in this book you are now reading There, too, at the close of the fifteenth century and the opening of the sixteenth, Aldus Manutius (ma nū'-shĭ-ŭs) spread learning among the people by printing inexpensive editions of the classics at his famous Aldine Press Aldus also devised the sort of type we call "italic," which is written *like this*

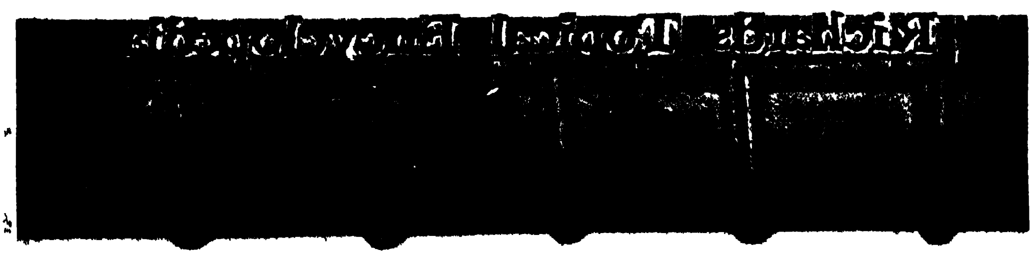
And it was in Italy in those days that the young Christopher Columbus pored over the printed account of Marco Polo's marvelous adventures in the East and the printed book of a scientist who proved that the world was round If you ever go to Seville, in Spain, you may get a barefoot Spanish priest to show you these books, with the name "C Colon, which is another form for "Christopher Columbus" written in them If printing had not been invented, would the famous admiral, or any other adventurer, have dreamed so greatly of a voyage to Cathay?

The art of printing was brought to England by William Caxton, who was born in Kent

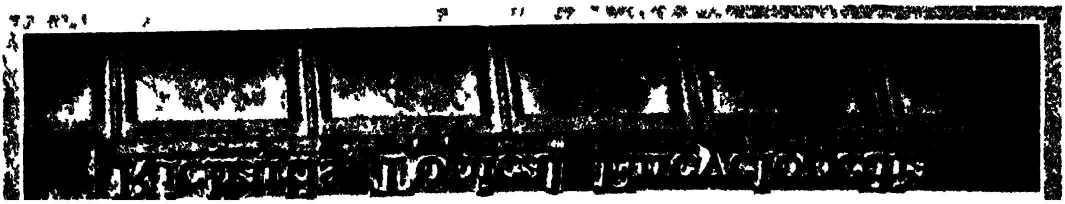
In 1476 William Caxton set up a printing press at Westminster. The artist of the picture above has tried to show what this most ancient of English publishing houses may have looked like. In the painting the "father of English printing" is showing a printed page to King Edward IV and his queen.

in 1422. Strange as it was for an ordinary person in those days, Caxton had a good education; even when he was an old man he still prayed for the souls of his parents, in gratitude for it. At fifty or thereabout Caxton found himself in the service of the sister of Edward IV of England, who had married the Duke of Burgundy and so was living in the Netherlands. Now Caxton was a fine penman and knew several languages; so, to give the princess pleasure and also to keep himself from idleness, which he called the

The linotype and its relative, the intertype, are fascinating machines When the operator pushes down the keys (3), matrices, held in the "magazines" (1), travel down the slides (2) to the assembly rack (4). Thin strips of steel (5) drop down between the words to make each line the same length When a line is complete, a touch of the finger will send the line to the mould chamber (6). The result is the "line-o'-type" shown below Then the machine sends the matrices see one in the oval back to the magazines



The language of the printer is short and to the point. These "slugs," or "line-o'-types," are made by shooting liquid metal against the face of the "mats," or matrices, and filling a mould to form the "body."



Photos by Kingsport Press Inc

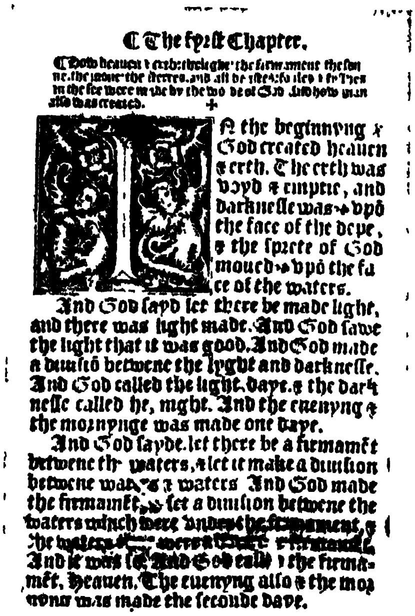
"mother and nourisher of vices," he started translating from French into English a book of romantic tales called "The Histories of Troy." It turned out to be a tiresome job, for, as he himself said, "his pen was worn, his hand wery and not stedfast, and his eyes dimmed with overmuch looking on the white paper."

So, being a clever and wide-awake man, he bethought him of the strange new bookmaking trade of some of his acquaintances at Bruges. He decided to have his book printed. And "The Histories of Troy," the first book ever printed in English, appeared in Bruges, about the year 1474.

Not long afterward, Caxton set up a press of his own in London, with a printer from Mainz to help him. There was no secret about the art of printing any more. Caxton sent out printed handbills saying that at the Red Pale on the premises of Westminster Abbey he would print and sell books "good cheape." And the books that came off this first printing press in England were nearly all of them in English. Caxton did not specialize in religious books after the medieval manner, but rather he loved romantic tales and legends, and books about hawking and games, such as delighted the lords and ladies of the court of his friend, King Edward IV. He printed the works of the first great English poet, Goeffrey Chaucer. He printed the "Morte d'Arthur," Sir Thomas Malory's great book of legends about the Knights of the Round Table.

But a great many of the books which Caxton wanted to print were in Latin or French. So he set to work to translate them himself, as well as to write prefaces to most of those that were written or translated by other people. In this way Caxton became not only a printer and publisher, but a rather important author, too. He did a great service to the English language, which at that time was going through a period of rapid change, and more than that, was so broken up into different dialects that a man from Devon, for example, could scarcely understand the speech of a man from Lancashire. In his editing and his translating, Caxton picked out what seemed to him the best forms and phrases, and helped greatly to steady and standardize the language For this he has been called "not only the father of English printing but the father of printed English." One of the changes which printing has brought to the world, as a matter of fact, is this very steadying of a language; languages change more slowly and split into fewer dialects when they are always being recorded in print and passed around among the people.

Another thing which printing has done is to make it possible for ordinary people to express their ideas and spread them about, and to learn of the ideas of other people. Without printing, we could hardly have either popular education or democracy. Now for this very reason, during the sixteenth and seventeenth centuries the men in high places distrusted printing; they did not want ideas to get about among the people. In 1660, for example, a royal governor of Virginia wrote King Charles II that there were, thank God, neither printing presses nor free schools in Virginia; he hoped there would be none


¶ The fyrst Chapter.

[illegible]

In the beginnyng God created heauen & erth. The erth was voyd & emptie, and darknesse was vpō the face of the depe, & the spirte of God moued vpō the face of the waters.

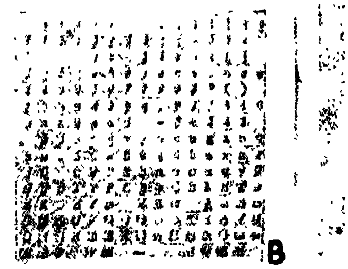
And God sayd let there be made light, and there was light made. And God sawe the light that it was good. And God made a diuisiō betwene the lyght and darknesse. And God called the light, daye, & the darknesse called he, night. And the euenyng & the mornynge was made one daye.

And God sayde, let there be a firmamēt betwene the waters, & let it make a diuision betwene waters & waters And God made the firmamēt, & set a diuision betwene the waters which were vnder the firmament, & [illegible] And it was so. And God called the firmamēt, heauen. The euenyng also & the mornyng was made the seconde daye.

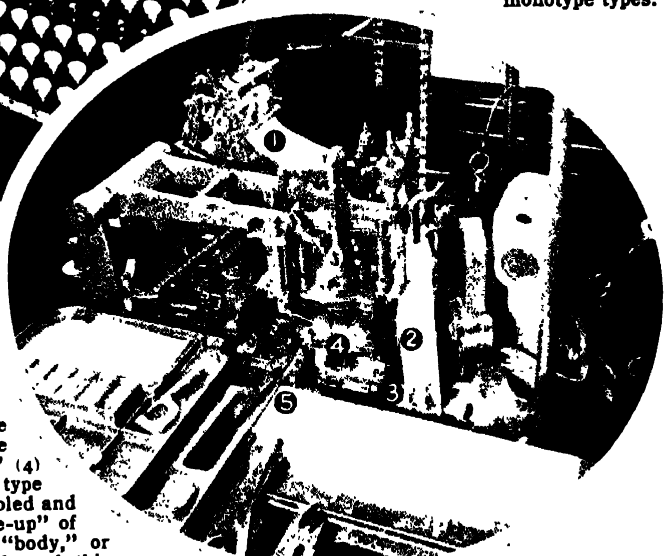
Photo by British Museum

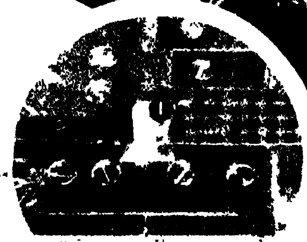
Can you read this beautiful page that tells of the creation? It is a page from the first of seven "Great Bibles" made at the command of Henry VIII between 1539 and 1541 for use in the newly-founded Church of England. The printing of this book was done mainly at Paris, but it was finished in England in 1539 by R. Grafton. This was the first English Bible that was officially authorized. And even then the mass of the people were not to have the privilege of reading it for long, for in 1543 parliament passed a law that "no woman (unless she be a noble or gentlewoman), no artificers, apprentices, journeymen, servingmen, under the degree of yoemen . . . husbandmen or labourers" should read the sacred book. To violate this law brought fines and imprisonment.

A. From this glorified type-writer keyboard, comes a perforated paper ribbon—like the kind used in a "player piano" that directs the type-casting machinery in the monotype "caster."



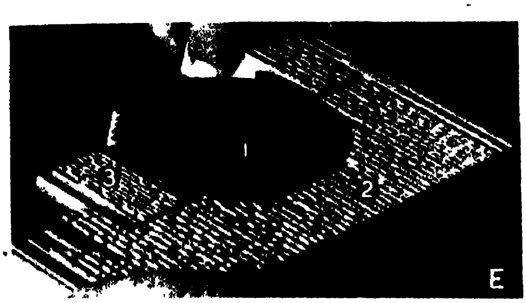
C. With a clatter like that of a dozen machine guns this complicated, fast-moving machinery, controlled by the perforated paper ribbon (1), produces in orderly array line after line of separate type pieces—all neatly arranged for the printer. B. These are the matrices—held in a matrix "case"—that shape the tops, or printing surfaces, of the monotype types.





D

C. Molten metal (2) must be forced against the face of the matrices in the matrix "case" (4) through a mould (3). The type thus formed is then quickly cooled and pushed out. At D is a "close-up" of the mould which forms the "body," or lower part, of the type. It is through this that the molten metal is forced against the matrices. At 1 is the hole in which the type is formed. A piece of type has been left in the mould to show you how it is cast. At E the printer is "making up" a book page of monotype to be used in the very book you are reading! In monotype each piece of type is separate, and so the words and letters can be broken up to fit around an illustration, or "cut," of any shape. At E a type page with illustration is being assembled. No. 1 is the engraving of an illustration; at 2 is the monotype type set around it; and at 3 is the caption—set in smaller type—that tells all about the picture. You are reading a bit of caption type at this very instant!



Photos by Kingsport Press Inc.

Photo Copyright by Franklin Printing C

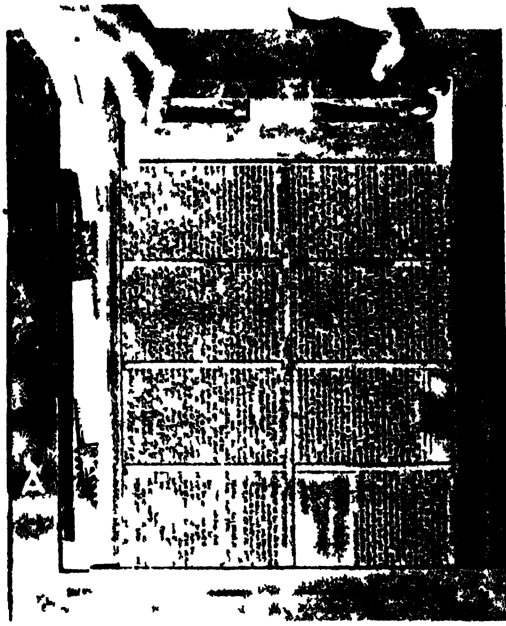
Benjamin Franklin is famous for a great many things—one of them is his printing house. Here in 1729 he brought out the "Pennsylvania Gazette," which was soon noted both for its superior printing and its sound journalism. In the picture above, you see him bringing in a load of paper on a wheelbarrow. He was such an able, energetic fellow that he seems to have found time to do his own trucking!

for at least three hundred years, since learning, which the printing press was scattering everywhere, had brought only heresy and rebellion.

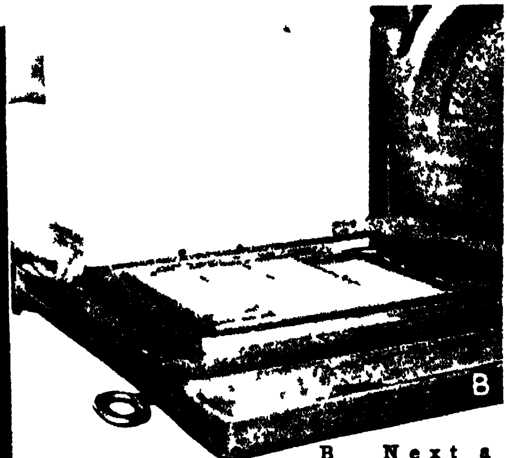
When Printing Was a Crime

The result of this sort of argument was that the authorities started censoring the press, telling it just what it could say and what it could not say. Heavy taxes were laid on printed matter. Daring printers were imprisoned, and obnoxious books were burned by the public hangman. Printing was more or less "driven underground," as we say; that is, presses often had to be worked in secret, and much of the printed matter had to be "bootlegged" to the people. Consequently, printing ceased to be an art, as it had been at first. Through these centuries, and on through the eighteenth and much of the nineteenth, the quality of printing degenerated

At the same time, the quantity of printed matter was continually increasing, and the knowledge of printing was spreading all over the world. The first printing press in the New World was set up in Mexico about 1539 Almost exactly a hundred years later (1638) "The Freeman's Oath" was set up in print in Cambridge, Massachusetts, on the first printing press in what is now the United States. Two years later the first book printed in the English colonies, "The Bay Psalm Book," came from the same press. This press, owned by Harvard University, has been printing good books ever since By 1800 there were more than a hundred printing establishments in Philadelphia alone.

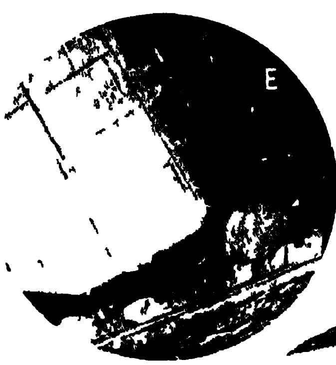


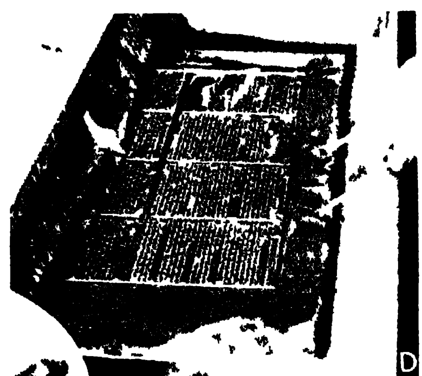
This page will give you some idea of how wax mould electrotyping is done A First the printer must "lock up" the type or slugs, in a steel case



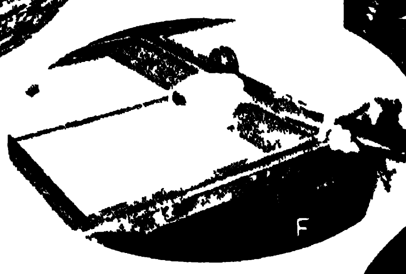
B Next a "mould," or impression, of the type "form" is taken by means of a wax "case"—a sheet of metal coated evenly with wax This impression is exactly like the form except that it is reversed as the *form* would look in a mirror.

C Every part of the wax mould where type does not appear must be "built up" by molten wax This is done so that the plate will be depressed where no printing is to appear If this were not done, unlovely black lines and splotches might decorate the page!





D Then the "case" is coated with a fine film of black lead to serve as a conductor A fine copper film is then precipitated on the mould by copper sulphate and iron filings E The sensitized mould is hung in an electrolytic "battery" in which pieces of copper are suspended An electric current causes copper to deposit on the "case" (cathode) from the copper anodes, forming a copper shell The printing surface is face down in the wax



F The shell is removed from the mould, trimmed, and strengthened on the reverse side by hot metal ladled out of a vat G A few finishing touches—such as shaving the plate down till it is very thin and it is ready for the printing press

Photos by Kingsport Press Inc

All this time, up to the beginning of the nineteenth century, the presses had been run by hand. Not until the end of the eighteenth century had there even been much change in the working of the hand presses; they were made of wood, and operated by being screwed down on the type. Then an iron press was devised by printers working separately in Philadelphia and London. Later inventors gave up the screw principle altogether and worked out a system of levers to get the necessary pressure.

But even before this had been done, the first power-driven press had been constructed (1811) in Germany. Next, the process of printing was speeded up still more when inventors began to set the type into revolving cylinders, and to fasten the paper to other cylinders which should be pressed against the inked type-cylinder in the process of revolving. After that the number of impressions which could be taken from a page of type rose steadily and rapidly. Not more than about 275 an hour could be taken by a hand press. By 1846 as many as 20,000 impressions an hour had been made by the bigger machines.

Photo by Mergenthaler Linotype Co.

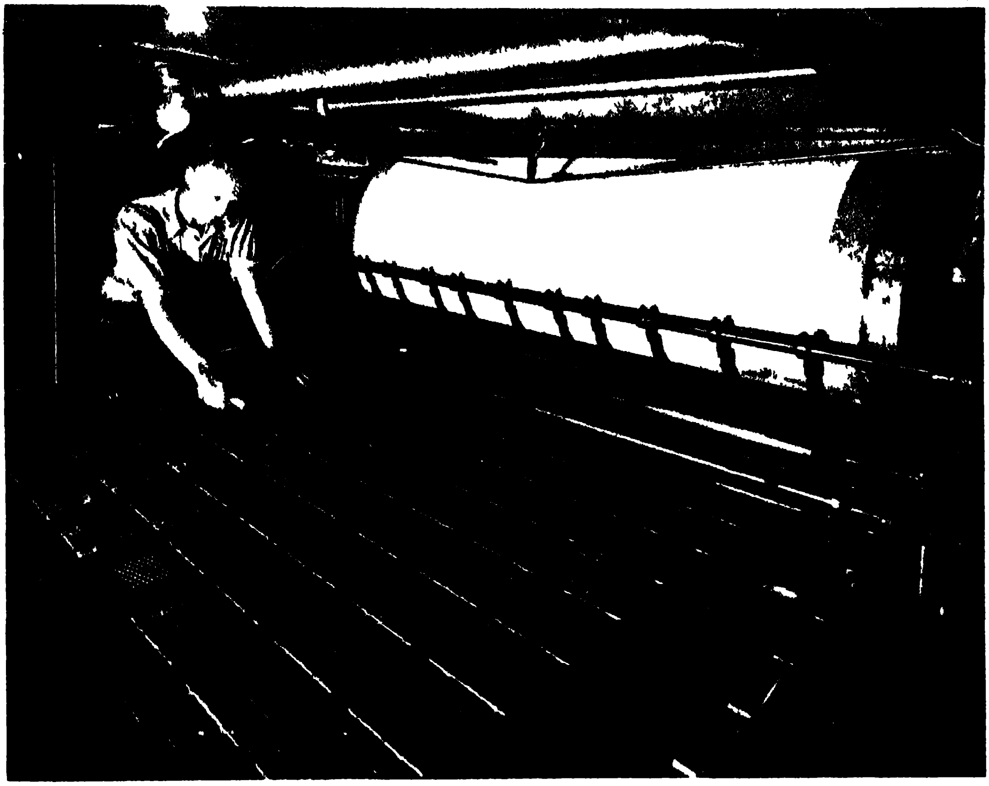
This is the linotype machine, used largely for setting the type from which the stereotyped plates that are used in printing newspapers are made. When operated like a typewriter, it turns out metal castings for each line of the type.

All through the nineteenth century and thus far in the twentieth, printing presses have been getting bigger and bigger, faster and faster, more and more complicated. To-day a newspaper press machine may turn out as many as 300,000 impressions an hour, more than a thousand times as many as the old hand press could make. But for a picture of a great modern newspaper plant and of the presses in it, you must turn to our article on the newspaper.

One of the longest and most ticklish jobs in the process of printing is setting up the type. Innumerable little bits of metal with different symbols on them have to be arranged in the proper order, each line the same length, the faces of all the type at the same level, every word spelled right, and every sentence properly punctuated. Until about 1820 all this had to be done by hand, as it is still sometimes done.

For this kind of typesetting every letter is cast separately, that is, for every letter on a page there is a separate "type," or tiny bar of metal usually lead alloy with the form of the letter standing in sharp relief, and of course in reversed position, at one end of the bar. All these types are sorted out—or "laid" into the various compartments of what is called the "case," a large wooden tray divided into numerous little boxes, each one of which contains the type of a single letter or symbol. The arrangement is not alphabetical. The letters most often used are grouped where they will be easiest to reach; and all the capitals go into one tray, called the "upper case," while all the small letters go into another, called the "lower case." You may see from these names that the small letters are nearer the typesetter's hand than the capitals, which are in the case above.

Now it is the task of the typesetter, or "compositor," to pick up these tiny bits of metal as swiftly and accurately as may be



[illegible]

Here the pressman is "laying" plates on the press "base" These plates, each of which represents a page, are held firmly by little "catches" on all four sides. When the plates are all in place, ink rollers, which you can see in the picture, will spread ink evenly over the printing surfaces.

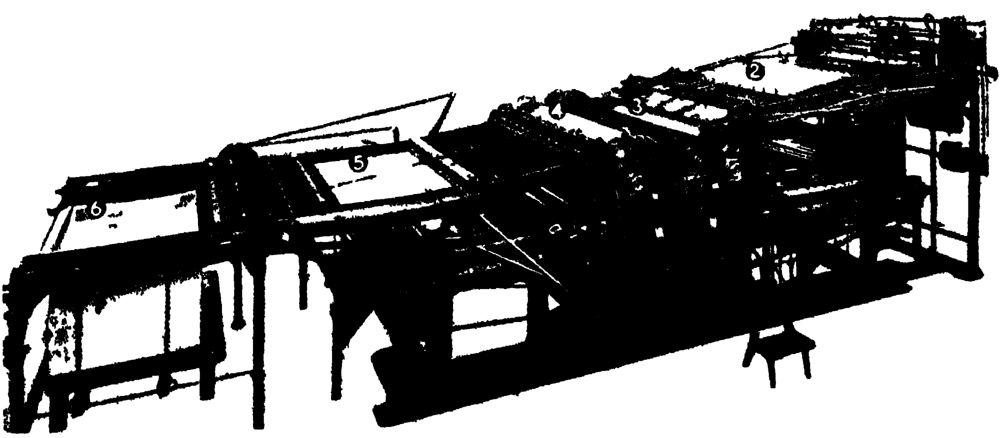
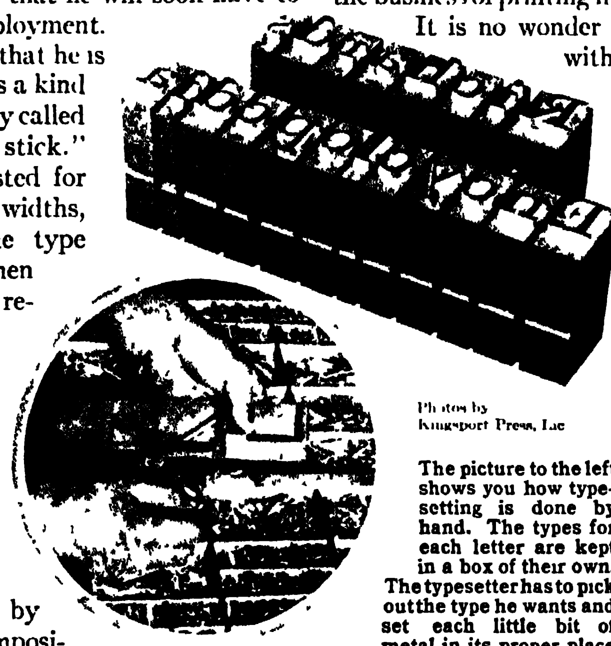


Photo by Kingsport Press Inc

This is a modern "two color press" This amazing machine prints at one time two colors on one side of a sheet large enough to carry as many as 128 or 256 pages. It can print 1,750 sheets in an hour. If you multiply that by the number of pages on a sheet—on both sides of the sheet, of course—you can see that it would not take long to print a book! At 1 is the "feeder" which, as you can probably guess, "feeds" the paper to this voracious printing press. At 2 the printing cylinder picks up the sheet of paper. The printing takes place at 3 and 4. At 5 a clever bit of mechanism takes possession of each printed sheet and passes it on to 6, where it is neatly placed on the rapidly accumulating pile of printed pages.

and stand them on end, "face" up, in the right order to spell out words—setting little metal strips called "spaces" between the words. It may not sound very hard, but it is really skillful work. Everything must be set up backward, as if you were seeing it in a looking-glass, and the compositor must know his "case" so well that his hand travels of its own accord to the little box that contains the letter he wants; for if it does not do so, he will be making so many mistakes and taking so long that he will soon have to hunt for other employment.

To hold the type that he is "setting up" he has a kind of narrow metal tray called a "compositor's stick." This can be adjusted for lines of different widths, and will hold the type firmly in place. When the stick is full, he removes the type to a long shallow tray called a "galley." From the galley a "proof," or impression, is printed, or "pulled," as the saying is, and on this proof all mistakes are marked by a reader. The compositor corrects these mistakes, and the type is then made up into pages, ready for further correction, perhaps, or for printing.



Photos by Kingsport Press, Inc

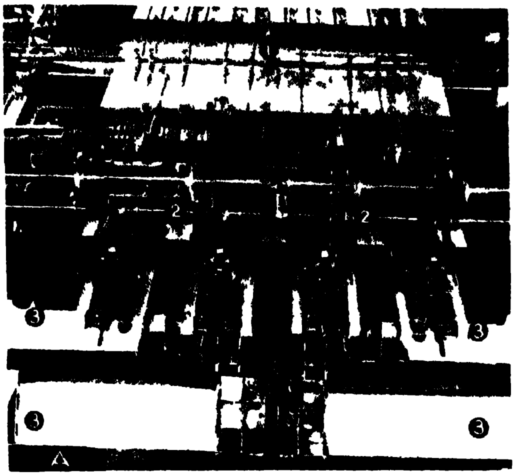
The picture to the left shows you how typesetting is done by hand. The types for each letter are kept in a box of their own. The typesetter has to pick out the type he wants and set each little bit of metal in its proper place in the "compositor's stick." He must work quickly and very accurately. Above is an enlarged view of the type used. A notch on the side of each piece helps the printer to set it in the stick in its proper position.

Of course in larger establishments the type is usually set by machine. One of these, the linotype, you will find described in our account of the printing of a modern newspaper. The other is called a monotype, because it casts every letter or symbol separately—the "mono" meaning "one." It is really two machines, a keyboard and a type caster. The operator, sitting at the keyboard, strikes the proper keys, and in doing so punches little holes in a moving ribbon of paper. Each combination of holes means a certain letter or other symbol. When he has punched a whole spool with these little holes, the spool is put on the casting machine, where the moulds and the molten metal are ready for it. In a very complicated way, the perforated strip of paper controls this mechanism so as to bring the right mould, or "matrix" (mā′-trĭks), into position at the right time, fill it with metal, and so cast the proper type, which is automatically removed to the galley. The type for the book you are now reading was cast and set in a monotype machine.

With all these mechanical aids, along with all the improvements in the making of paper, the business of printing moved at a rapid pace. It is no wonder that we are flooded with printed matter in these days. Instead of one person in five hundred knowing how to read, we think it a shame if any adult or half-grown child does not know how. We cannot sit for fifteen minutes in a train, bus, or trolley car or even hang to a strap that long—without having our noses buried in newspapers. If all else fails we read the advertisements along the wall, no matter how tiresome and silly they may be. Sometimes, in moments of exasperation, we could almost wish that Gutenberg had never had his great idea!

How the Blind May Read

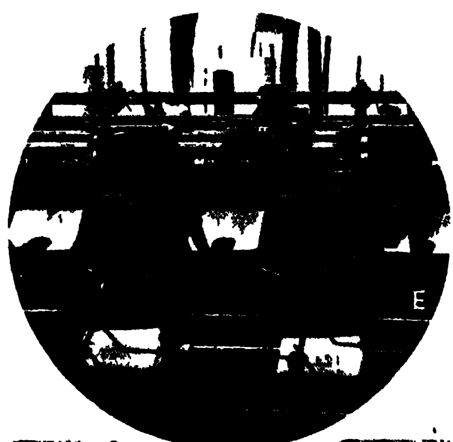
But, of course, we would not think of giving up the vast benefits of knowledge and entertainment which printing has brought us. It is heartening to think that nowadays even the blind can be taught to read. For various systems of printing in relief—that is, with symbols raised from the page so that they can be felt with the fingers—have been worked out. The most widespread of these systems is Braille (brāl), which uses a system of dots, arranged in an oblong, to represent



Have you ever stopped to wonder how books are bound? The huge sheets that come from the printing press, with many pages printed on both sides, must be folded and separated into sections, or "signatures," of 8, 16, 32, or 64 pages each. Signatures are shown at B and C

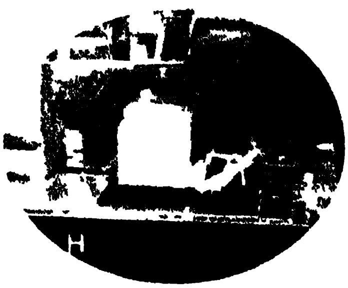
A. This is the machine that separates the pages. Folding machines take the printed sheets, feed (1) them, one at a time, through rollers (2 and 2) and cutters that separate each sheet into signatures, which are delivered, neatly folded, to troughs (3)

C



D Pasting in pictures that must appear inside the signatures. E Machine that assembles the signatures. When it makes a mistake, it stops and raises a metal hand!

G. A "smasher" that squeezes books to an even thickness. H. This guillotine trims pages

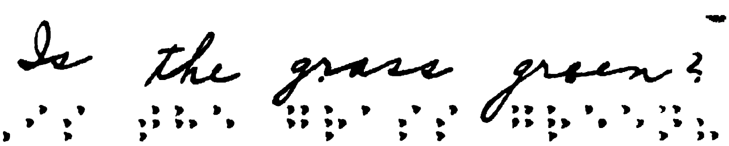


F. An automatic sewing machine that sews the signatures together.

Photos by Kingsport Press Inc.

Photos by American Foundation for the Blind

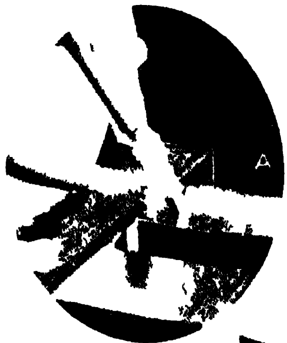
Clever, sensitive fingers passing over tiny mounds on a sheet of paper can read as rapidly as anyone could wish. Above, you see the hands of a blind person who is reading a sheet of Braille. This sheet was typed out on a Braille typewriter. As you can see below, the words are translated into a code, a certain arrangement of dots raised above the surface of the paper stands for a letter. This marvelous invention has opened up our world to the blind. Instead of being shut off in a dark realm of their own, dependent upon their friends who can see, they can now read and write and do a great many useful things. For this we must thank Louis Braille (1809-1852), the blind French organist who invented the system.



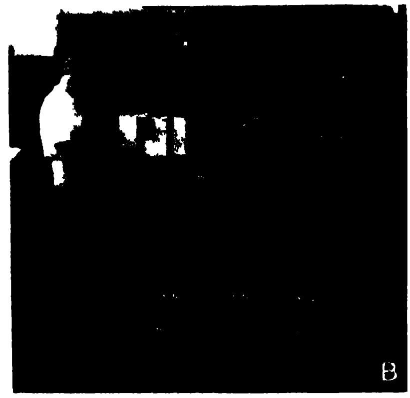
all the letters and marks of punctuation and even the notes of music. Since World War I a great deal of progress has been made in teaching the blind to read.

Of course the printing process is used for many other purposes besides for the reproduction of reading matter. The fine line engravings, etchings, mezzotints, and woodcuts with which our books and walls are adorned are all "prints." The first of these is now pretty much out of style, though in the last century a fine "steel engraving" was highly prized, and many of them had a great deal of beauty. They were printed from copper, or sometimes steel, plates on which the picture had been scraped, or rather dug out, in fine lines with a sharp metal instrument called a burin (bū'rin). The engraver pushed the burin's triangular point forward as he worked, and so turned up a tiny shaving of metal. When the design was finished, the plate was covered with ink —not of the kind we know best, but of a much dryer kind which will not run. This was wiped away, except for what remained in the grooves that the burin had made. Then a sheet of damp paper was laid against the plate and pressed down hard, and when it was pulled away it brought the ink away too. In this way all the fine lines on the plate were transferred to the paper.

Men had for centuries been engraving beautiful designs on gold and silver before anyone had the notion of filling those lines



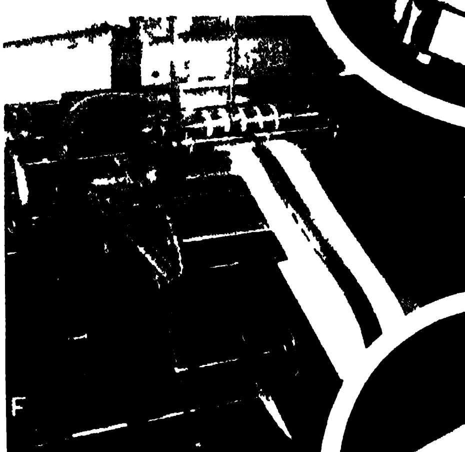
This page shows you the artistic side of bookbinding. A. Burnishing the gold-edged pages. The gold 22-carat gold leaf—was laid on after the edges were smoothed B. Air guns do solid colorings or imitation marbling E. Machine which gives books a rounded back and concave front.

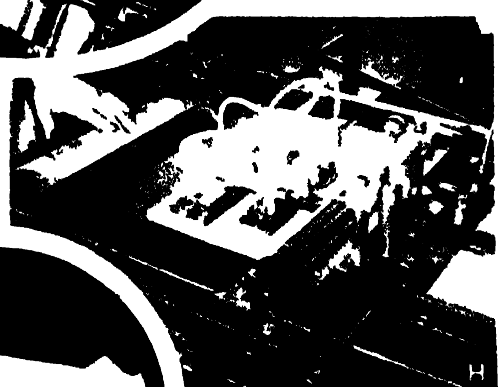


C Before machine at E has done its work

D After machine at E has done its work Note rounded back

H. Covers are made in clever machines which feed the ribbons of cloth around a drum to be coated with glue. From magazines come the "boards" and paper "backbone" lining. The materials are combined ready to have edges and corners "turned in"



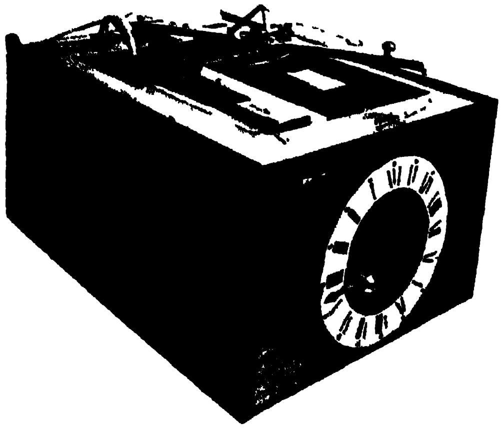


I. Machine that stamps raised or recessed designs on covers.

G Muslin, paper, and "flexible" glue are used to give a book a firm, flexible back

F. A glimp · of the huge machine that spreads "flexible" glue on the backs of books and adds muslin backs and decorative head bands. J Combining books and covers A book goes through a machine which coats it with paste, it is slipped into a cover by machinery, and is dried in presses for several hours.

Photos by Kingsport Press Inc



It was in 1714 that the first patent for a typewriting machine was issued, by Queen Anne, to an Englishman named Henery Mill; but we know nothing about his machine. In 1829 William Austin Burt of Detroit patented a machine like the one shown above. It carried the type, not on individual bars, but on a curved band of metal that was a segment of a circle. Though people in many countries were working on the invention, it was not till 1868 that C. Latham Sholes and Carlos Glidden, both of Milwaukee, patented a machine which was developed into the world's first practical typewriter. In 1874 E. Remington and Sons put the first typewriters on the market. In them the type was carried on individual bars, and a foot tread operated the carriage return. The arrangement of the letters on the keyboard was almost exactly as it is to-day on what is known as the "universal keyboard" used on machines of all makes. But those first machines could write only capital letters.
As time went by, typewriters were greatly improved. We take the typewriter for granted, and do not realize that it was one of the most important inventions of the last century. Modern business could hardly be carried on without it; the need for people trained to use it opened up the vast new field of business education; and probably most important of all its introduction into offices threw open the doors of the business world to women. A number of other inventions depend upon it for instance accounting machines and the teletype, a device by which a typist at a typewriter in one office can tap out a message that goes by wire or radio to be registered on paper in another office hundreds of miles away.

Eventually, when more and more typists came to use the "touch system" that is, to type without watching the keyboard the machines with a shift key came into universal use. On these machines one key on the keyboard will write both capitals and small letters. A "shift key" merely shifts the cylinder that carries the paper. Later, machines were devised which allow you to see what you are writing. And portable machines were built—so light and compact that you can carry them about. The latest invention is the noiseless typewriter, in which the type bar presses, instead of striking, the type against the paper.

with ink and printing from them; and it was not till the sixteenth century that the art came into its own. Albert Dürer (dü'rĕr), a German, was undoubtedly the greatest line engraver who ever lived. To-day, visiting cards and such things as wedding invitations are still engraved in this way; and if you rub your finger over their surface you can feel the raised outline of the ink which has been pulled out of the grooves on the plate.

What Is an Etching?

An etching, too, is printed on damp paper from a copper plate, in the same way as a line engraving. But an etched plate has never felt the bite of an instrument, except on rare occasions when the artist makes a few of his lines deeper and stronger with the point of a needle. All the lines on an etched plate have been eaten out with acid. First, the surface of the copper is covered with a thin coat of wax. In this wax the design is drawn with a needle, deeply enough to cut quite through the wax to the plate below. Then strong acid is applied and allowed to eat the surface of the plate wherever the wax has been scraped away. For very deep, dark lines the acid is allowed to remain on the plate longer than for the lighter lines. When the acid and wax are removed, the plate is ready for printing.

Sometimes, though not often, a design is scratched directly on the copper plate with a needle. A plate of this kind is known as a "dry point."

The World's Greatest Etcher

Our oldest known etching was made in Germany and is dated 1504. The gifted Dürer tried his hand at the new art; but probably the greatest etcher who ever lived was the seventeenth century Flemish painter Rembrandt (rĕm'bränt). Many other etchers have been famous. Sir Seymour Haden,

This page will show you how a "four color" print is made The four colors, in the order in which they are used, are yellow, red, black, and blue But those four colors give many shades and tones

The printer uses four plates, one for each color In making a plate he must know exactly where the various shades of a color go and how much space they cover.

Engravings by Capper Engraving Co Knoxville Tenn who made the engravings for the Richards Cyclopedia

First he puts on the yellow then the red. The dark tones of one overlapping dark tones of the other, produce orange Black outlines the picture and blue completes it

The plates must be carefully measured and adjusted; otherwise, instead of this clear picture you would see blurred edges and misplaced outlines with overlapping colors.

William Strang, and D. Y. Cameron in England; Charles Méryon (mā'rē'oN'), Charles Jacque (zhăk), and Alphonse Legros (lē-grō'), all of them Frenchmen; the Italian Piranesi (pē'rä-nä'zē), who was an engraver as well; the Scandinavian Anders Zorn; and the Americans J. M. Whistler and Joseph Pennell—all of these are men whose names you will often see if you like to look at fine prints.

These pictures show you three steps in the process of etching, or "intaglio printing." First, the design is drawn with an etching needle on a sheet of thin copper. This sheet has been coated with a preparation of wax that will resist acids. The needle itself is a sharpened piece of steel. The artist, in drawing the design, removes part of the wax and exposes the copper underneath.

The plate is then "etched" with a mild "corrosive," an acid which eats out the copper where it has been exposed. The longer the acid is left on, the deeper the lines will become. Then the acid and wax are removed and the plate is ready for printing. Ink is applied to the plate with a dauber and then rubbed off with the palm of the hand so that no ink remains except in the etched lines. The print is then made on damp paper in a hand press under heavy pressure. We say that the print is "pulled," for literally the ink in the lines on the plate is pulled out on the paper.

The plate for a mezzotint (mĕd'zō-tĭnt) differs from the two kinds of plates we have just described in that before the design is drawn upon it the whole surface of the plate is roughened with a "cradle" or "rocker," a curved metal instrument on which are innumerable very fine projections. These bite into the metal as the instrument is rocked back and forth over the surface of the copper, and produce a "burr" that looks almost like plush. When this worked surface is inked the impression taken from it will be almost as black and soft-looking as velvet. Next the artist sets to work to scrape the burr away, and to dig out and burnish the "ground" of the plate wherever he wants very light patches to appear on his print. When the plate is inked he will wipe these patches clean. The impression pulled from the finished plate has much the quality of painting. There are few sharp lines, but many lights and shades. That is why it is called a "mezzotint"—"half tint."

As we said at the beginning, prints were first made from carved wooden blocks—and they are often made in that way still. Before processes for reproducing photographs were perfected, the great majority of our illustrations were these "woodcuts," and one still sees many of them to-day. Such work is done by craftsmen. But since the opening of the present century genuine artists have grown interested in this old, old art form and are engraving and printing woodcuts that are very beautiful indeed.

All woodcuts are made by cutting away portions from the surface of a solid block of wood. Such parts as are cut away will be white on the print, for the paper will not touch them. The parts of the block's surface that are left untouched will be black, for these will take the ink and leave it on the paper.

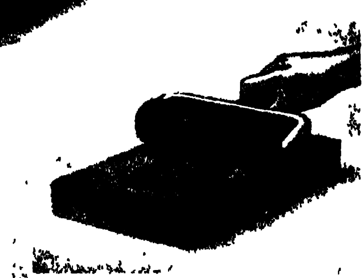
There are two kinds of woodcut. In the "black-line" cut—and strictly speaking, this is the real "woodcut"—the design is first drawn in dark lines on a thin block cut from a plank of some soft wood like apple or sycamore. Then the wood is cut away on all sides around these lines, so that only their outline is left standing. From such a cut you will get a print consisting of black lines on a white ground.

The second kind of cut, known as the "white-line cut," or "wood engraving," is cut into the end grain of some very hard and fine-grained wood—usually box wood. Instead of cutting away all but the dark lines, the artist begins by gouging out grooves which shall be white lines; and so developing his design—white spaces appearing on the dark ground as he works.

Still another kind of print is taken from

stone—or often nowadays from a zinc or aluminum plate or some other suitable substance. This process for printing is called "lithography" (lī-thŏg'rȧ-fī), and a print so made, a "lithograph" (lĭth'ō-grȧf)—the word means "stone writing." On a smooth, fine-grained block of stone the artist draws his design with an especially prepared greasy ink or crayon made of wax, soap, oil, and lampblack. The design may also be transferred to the stone by the use of an especially prepared paper. A preparation of acid and gum arabic is then washed over the stone, its purpose being to destroy every atom of grease on the stone except that which is contained in the crayon, where the grease is protected by the wax. This process of destroying the extra grease is called "etching"—but it is very different from genuine etching, in which a portion of the plate is actually eaten down.

Here are three steps in the process of lithography, which you will find explained on these pages. To the left the artist is drawing the design on stone with a grease crayon.



Next, the stone will be etched with a mild acid solution of nitric acid and gum arabic, but the crayon will protect parts of the stone from being eaten by the acid. Then the stône will be moistened with water, which will cling to the part of the stone that was acted upon by the acid, but will not cling to the greasy crayon design. In the center picture, the stone is being inked with a greasy ink. Now since oil and water will not mix, the wet parts of the stone will repel the ink, which will therefore stick only to the greasy crayon. When the print is made, therefore, the design that was drawn on the stone in crayon will appear in ink on the paper, as shown in the circle at the right.

Now you must often have noticed that water and grease repel each other. It is this fact that makes lithography possible. When the stone has been moistened, a thick greasy ink is applied with a roller. The ink will not stick to the wet parts of the stone, but will cling nicely to the greasy crayon with which the design was drawn. So when a piece of paper is laid against the stone, the design is printed neatly upon it by the ink that clings to the crayon.

The Marvels of Modern Printing

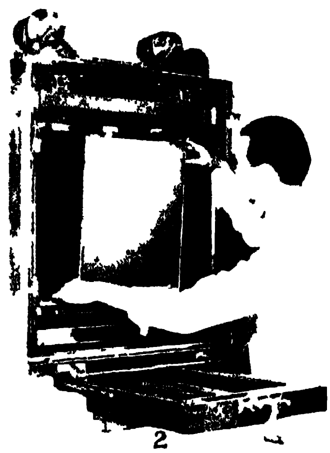
Lithography was invented in 1798 by a Bavarian actor and dramatist named Alois Senefelder (zĕn'ĕ-fĕld'ĕr); and during the early nineteenth century it was used widely, especially for illustrations. Then it almost died out, for photographic reproductions were much cheaper. Of late, however, artists have begun to make beautiful lithographs.

We have not space to describe the many amazing and skillful processes that have been worked out by the printers—such, for instance, as printing in color. In fact, since the latter part of the nineteenth century there has been quite a revival of printing as an art. William Morris, with his famous Kelmscott Press in England, had a good deal to do with it, as he had to do with the new interest in beautiful furniture and other beautiful things; and the great demand for printed matter helped things along. There is very much less interfering with the press by the authorities than there used to be. Of course a large part of the incredible amount of printing that is done now is done hurriedly, as cheaply as possible, with the idea that it will be read or skimmed through and then thrown out or used to line the pantry shelves. But at the same time, an ordinary book is immensely better printed than it would have been a century or two centuries ago. And certain fine editions are being produced here and there that remind one of the brave days of the Renaissance, when printing was still a rare thing, and an art.

So when you pick up a book, try to remember that it is a work of art as well as a thing for use.

Have you any idea of the great number of things that have to happen before a photograph can be reproduced in a book this book, for instance? This page and the pages following will show you the steps in the process of "photo-engraving" Fig 1 Plain glass, washed chemically clean, is flowed with an albumen solution Then it is dried, coated with an iodized collodion, and put in a silver nitrate bath, which makes the plate sensitive to light

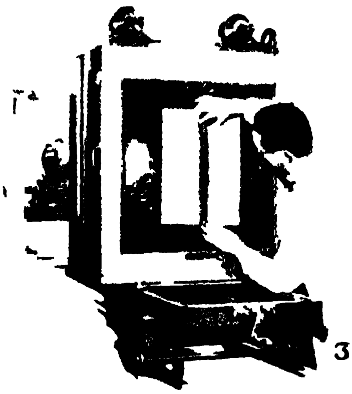
1



2

Fig 2 A glass "screen," on which are about 120 horizontal and vertical lines per inch, is placed in the back of the camera The sensitized plate will be placed just back of this screen

Fig 3 The image to be reproduced is illuminated by arc lamps and focused to the correct size on a large ground glass The glass is then removed and a sensitized plate is placed in the camera and exposed



3

Fig 4 The negative is developed and corrections made in a dark room Fig 5 After it has dried, the negative is coated with rubber and collodion

4

5

The coating of rubber and collodion was put on so that the film could be removed from the glass After coating, the negative is cut to the desired length (Fig 6) and soaked in an acid solution which loosens the albumen under the coating

6

Fig 7 The film is then lifted easily from the glass and is grouped with other films on plate glass of a standard size.

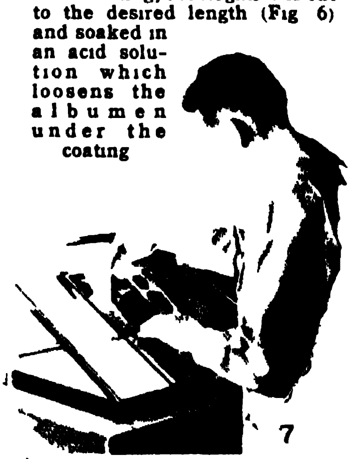


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Fig 8 Excess water underneath the films is squeezed out with tting paper The films are then dried and are ready for printing on copper or zinc

8

Photos by Keystone Photo Engraving Corp

9

Fig. 9. A piece of copper or zinc is cut to size, thoroughly cleansed with water, and coated with a solution of albumen and ammonium bichromate. This sensitizes the metal to light.

10

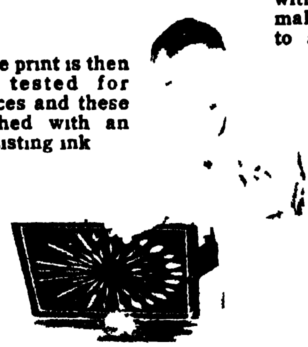
Fig 10. The negatives are then laid face down in direct contact with the sensitized metal and exposed to strong light for several minutes. This prints the object directly on the metal.

11

Fig 11 The print is then washed with water, dried, and carbonized with heat. This carbonization makes parts of the print resistant to acid when it is placed in an etching bath.

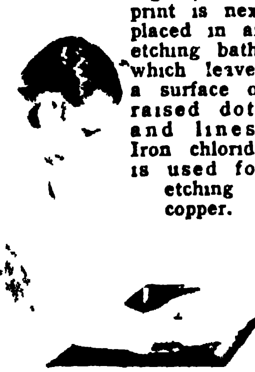
12

Fig 12. The print is then carefully tested for broken places and these are retouched with an acid-resisting ink



13

Fig. 13. The scum which was picked up in the process of printing is removed with a permanganate solution before etching.

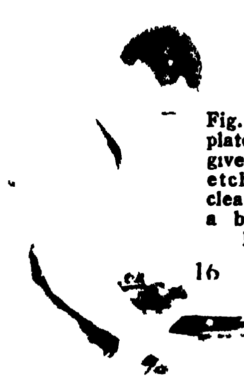


14

Fig. 14. The print is next placed in an etching bath, which leaves a surface of raised dots and lines. Iron chloride is used for etching copper.

15

Fig. 15. After an initial etch, the copper plate is then filled with chalk and carefully retouched with "staging ink" to bring out certain details more clearly.



16

Fig. 16. The plate is then given a second etch and is cleansed with a benzol solution.

17

Fig. 17. The chalked plate is then compared with the original copy and corrections made by re-etching.

Photos by Keystone Photo Engraving Corp

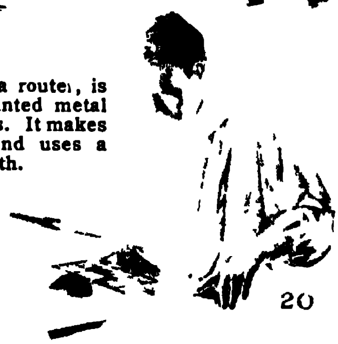
18

Fig. 18. This machine, called a router, is used for cutting away all unwanted metal and for deepening line engravings. It makes 13,500 revolutions a minute and uses a small steel bit to cut with.

Fig. 19. Engravings are nailed—either by machine or by hand—to especially prepared wood.

19

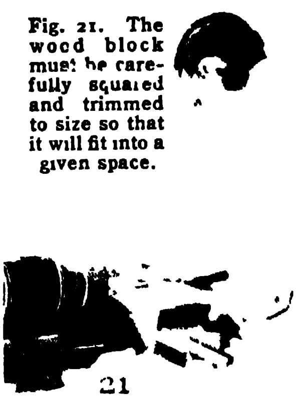
Fig. 20. The copper plate is sawed up to separate the different engravings on it.



20

Fig. 22. After being "squared up," the bottom of the wood block is planed until it is exactly as high as the types are.

Fig. 21. The wood block must be carefully squared and trimmed to size so that it will fit into a given space.



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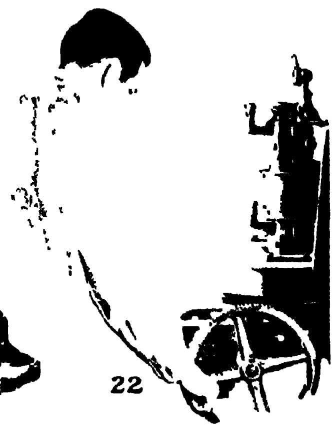


22

23

Fig. 24. The unwanted metal is then cut away with the routing machine and the rough edges are trimmed with an engraving tool.

Fig. 23. All of the unwanted surface is outlined by hand with a graving tool.

Fig. 25. Special white lines to separate the individual pictures are cut with a draw tool.

Fig. 26. The high lights are re-engraved and all special tooling is done by hand.

24

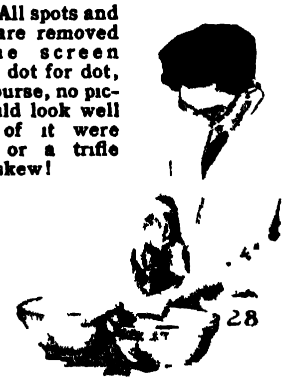
25

26

Photos by Keystone Photo Engraving Corp

27

Fig 27. All spots and defects are removed and the screen matched dot for dot, for, of course, no picture would look well if part of it were missing or a trifle askew!



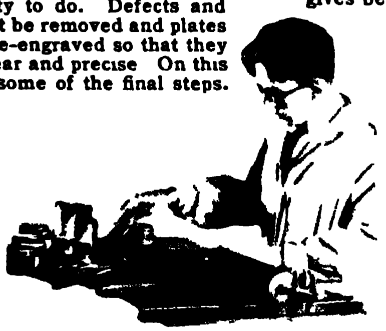
28

Fig 28. The finished engraving is washed with an acid solution to remove all magnesia and every grease spot.

Even after all the careful work that has gone into the making of our "half-tone plates," the finishing department has found itself with plenty to do. Defects and spots must be removed and plates must be re-engraved so that they will be clear and precise On this page are some of the final steps.

29

Fig 29. Paper overlays are cut to fit engravings that have been outlined and vignetted This gives better proofs.



30

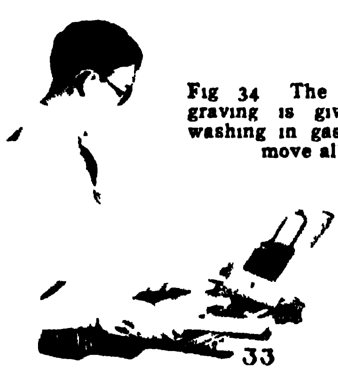
Fig 30. Inks are mixed to the required color or shade and then rolled out thin with a composition roller

31

Fig 31 Color plates are registered by a square form with very minute adjustments This device fixes the positions of both the engraving and proofing paper.

32

Fig 32 The engraving is then inked and proofed on the grade of paper suitable for it This is done by placing it under enough pressure to transfer the ink to the paper A hand press is commonly used.



33

Fig. 33. The proof is then compared with the original copy to find out whether it is accurate in every detail.

34

Fig 34 The finished engraving is given a good washing in gasoline to remove all ink

Photos by Keystone Photo Engraving Corp

A. Photo-engraving made from a screen of 175 lines per inch.

B. Photo-engraving made from a screen of 150 lines per inch.

C. Photo-engraving made from a screen of 133 lines per inch.

D. Photo-engraving made from a screen of 120 lines per inch.

In order to make a photo-engraving, or "half-tone," the photograph to be reproduced must first be photographed through a screen, which may be coarse or fine. A screen is made of two sheets of glass ruled diagonally with opaque lines and cemented together with the lines at right angles. The "screen negative" shows the lines of the screen and, in between them, as much of the original photograph as could affect the negative through the tiny open squares of the screen. Light passing through this negative and falling on a sensitized metal plate, reproduces the picture and screen. The plate is then eaten away with acid, leaving a roughened printing surface of dots and lines, such as you see at H. These are really what is left of the lines on the sensitized plate. Those lines, when the plate was exposed to the light, became hard and resistant to the etching acid the darkest parts offering the most resistance.

E. Photo-engraving made from a screen of 100 lines per inch.

F. Photo-engraving made from a screen of 85 lines per inch.

G. Photo-engraving made from a screen of 65 lines per inch.

H. Photo-engraving made from a screen of 50 lines per inch.

Photos by Giraudon, Paris

Reading Unit
. No. 7

THE NETS THAT CATCH THE NEWS FOR US

Note: For basic information not found on this page, consult the general Index, Vol. 15.

For statistical and current facts, consult the Richards Year Book Index.

Interesting Facts Explained

The first newspaper, 10-73
How Roman generals learned the news of the empire, 10 73-74
The first regular newspaper, 10-74
Early colonial newspapers, 10-74, 76
How cheap newspapers were made possible, 10 76-77
The Associated Press and the United Press, 10 73, 79-80
The journey of a reporter's story, 10 80-82
In the United States, many millions of newspapers are printed daily, 10-81

Things to Think About

Why were many early newspaper publishers persecuted?
Why were press news associations formed?
What difference did the coming of the telegraph and the ocean cable make to the newspaper publishers?
How was news gathered before the telegraph was invented?

Related Material

How are speech sounds transmitted over great distances? 10 112-13
How are pictures sent by telegraph? 10-94-99
How did ships at sea get the news of the world in 1904? 10-116
How are messages sent and received by telegraph? 10 95, 97-98
How is news sent across the sea by telegraph? 10 101, 106
How does the radio broadcast the news? 10 115, 119, 121
What is the life history of the paper we use for our newspapers? 9 275-80
Of what use is a teletype machine in a modern newspaper office? 10-99

Practical Applications

Why is a fine newspaper one of the bulwarks of our modern civilization? 10-81
Why do newspapers print advertising? 10-79-80

Summary Statement

When the price of paper fell and when improvements were made in printing processes, it was possible for everyone in civilized countries to have all the news for a few cents a day.

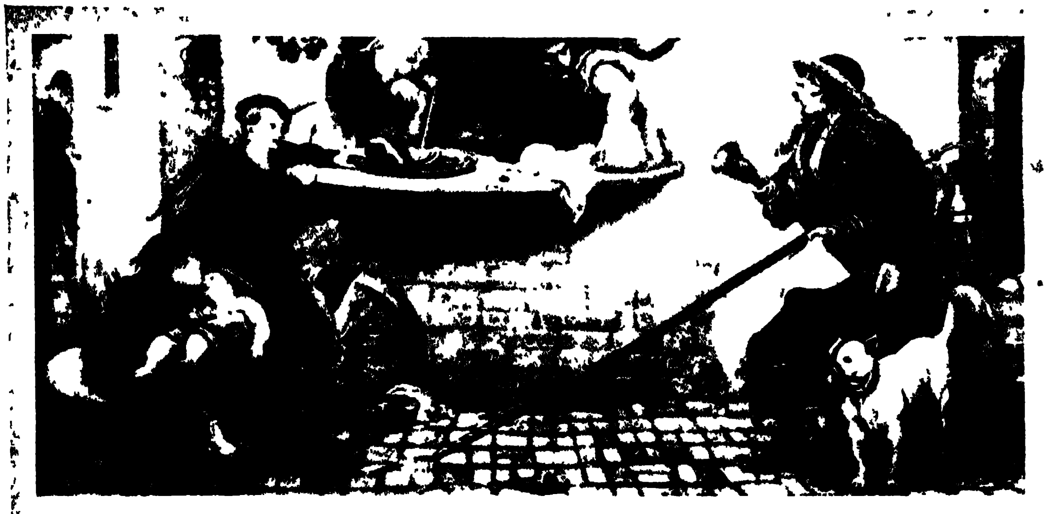


Photo by Corporation of Manchester

"Hear ye! hear ye!" The town crier's voice booms and his bell clangs merrily as he goes through the streets telling the news. The crier in this picture must have lived in the days since printing was invented, for he seems to be carrying a printed handbill announcing some important bit of news. Or is it a royal proclamation, which the good man has got by heart by dint of repeating it so often on his rounds?

The NETS THAT CATCH *the* NEWS *for* US

How the Paper on Your Breakfast Table Finds Out All It Tells You and Puts All the News Together in the Night

ONE Monday morning not very long ago people at breakfast in cities all over the United States read in their newspapers that the steamer "Tahiti" was sinking not far from the island of Suva. The time given for the message from Suva was 9:30 Monday morning. But in small type just under the headlines of the item was the statement: "Received by Wireless from the Associated Press, New York, 7:30 P.M. Sunday." So what was actually happening at 9:30 Monday morning off a lonely little dot of an island in the Pacific had been known in the New York newspaper offices at 7:30 on the Sunday evening before. News of it had been sent to papers all over the United States, had been set into type, and printed in the dailies that showered off the presses some time between one and three o'clock in the morning; and you and I had read it at eight or eight-thirty Monday morning, an hour or more before it was supposed to have happened out at sea!

Of course, as you have already guessed, that strange matter of the time is very easily explained. Suva is over on the opposite side of the earth from New York, and so it is Monday morning in Suva while it is still Sunday evening in New York. But for all that, the incident shows how quickly news is spread around the earth, and how fast our great dailies can get it to the people.

Like the story of printing, the story of the printed newspaper begins far back in China centuries ago. Long before the nations of the West had any kind of news sheets, a sort of news bulletin was published in Peking to circulate governmental rulings and decrees. It was printed from wooden blocks.

And centuries before that, the "Acta Diurna"—or "Daily Doings"—was sent out to generals in the Roman armies all over the world, to let them know the news of the empire. It was not printed, of course, but just written. Now and then other items besides governmental news were put in as spice for the men in some lonely post in Thrace or Britain. For instance the "Acta" of one April day some sixteen centuries ago

told how lightning had struck a house on the Palatine Hill in Rome, how the proprietor of the Hog in Armor Inn at the foot of Banker Street had been hurt in a tavern brawl, and how several butchers had been fined for selling meat that had not been inspected by the market overseers. There must have been some pleasant things happening in Rome that day, but apparently the noble Roman generals were a good deal like many of the more ignorant people in our own day—they liked to read about crime and horror rather than about the more important doings of the human race.

In the fifteenth century the city of Venice published a hand-written government news letter once a month. It sold for a "gazetta," a coin worth about half a cent. So you can see how we came to call a newspaper a "gazette." Long after printing from movable type had come to be known in Italy, this bulletin was still written out by hand, for the government did not want too many people to read it.

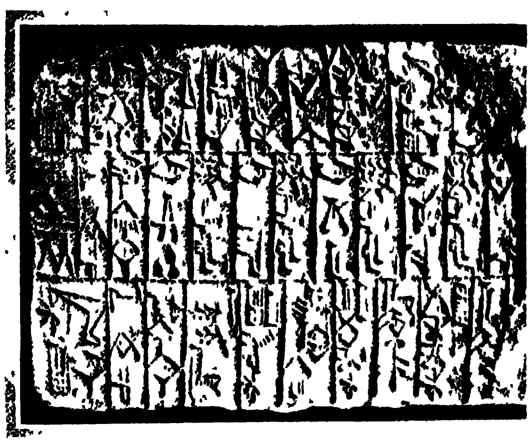


Photo by British Museum

A clay tablet like this, cut with characters carrying a proclamation from the king, is about as near as the ancient Babylonians came to a newspaper. It would not be very convenient for reading in a crowded train or bus.

The First Regular Newspaper

It was not long before several of the German towns had their printed news sheets. In 1615 a German news weekly called the "Frankfurter Journal" began to appear, the first printed news publication to come out regularly. In 1622 the "Weekly Newes" was regularly published in London.

In the last half of the seventeenth century England and Scotland began to delight in any number of attractive little places known as coffeehouses. They were just as good as a newspaper for the men who gathered there to drink the delicious new beverage. All the latest gossip passed rapidly from mouth to mouth, and there was always a lively discussion of the topics of the day. It was not long before some enterprising person had the bright notion of going from one coffeehouse to another to gather up the news and then sending it to regular customers outside of London. Country gentlemen were very proud of their weekly "news letters" containing notices of important events and all the gossip of the court. These news letters soon became very popular, but they had to make way against one great disadvantage. Though England had had printed news bulletins ever since the time of Queen Elizabeth, the publishers had always been so hampered by heavy taxes and strict laws as to what they might publish that there was no wide circulation for any one paper until after the severe press laws were abolished in 1695.

Five years before that date the first newspaper printed in America had brought its publisher into trouble. This was Benjamin Harris, who had come from London. Back in the old country he had dared to print a paper criticizing King James. For this crime he had had to pay a fine of £500, stand in the pillory for an hour, and serve a term in Newgate, one of the most terrible of all the prisons in history.

As soon as he was free, Harris came to Boston, where he and his wife opened a "Coffee, Tea, and Chucaleto" shop. Before long he brought out his "Publick Occurences," in which he promised to publish once a month "such considerable things as have arrived unto our notice." This first real newspaper of ours was printed on three sides of a folded sheet, and had two columns eleven inches long and seven inches wide to the page. Just remember that, when next you pick up the Sunday paper on your doorstep!

"Publick Occurences" contained items telling how the Christianized Indians were

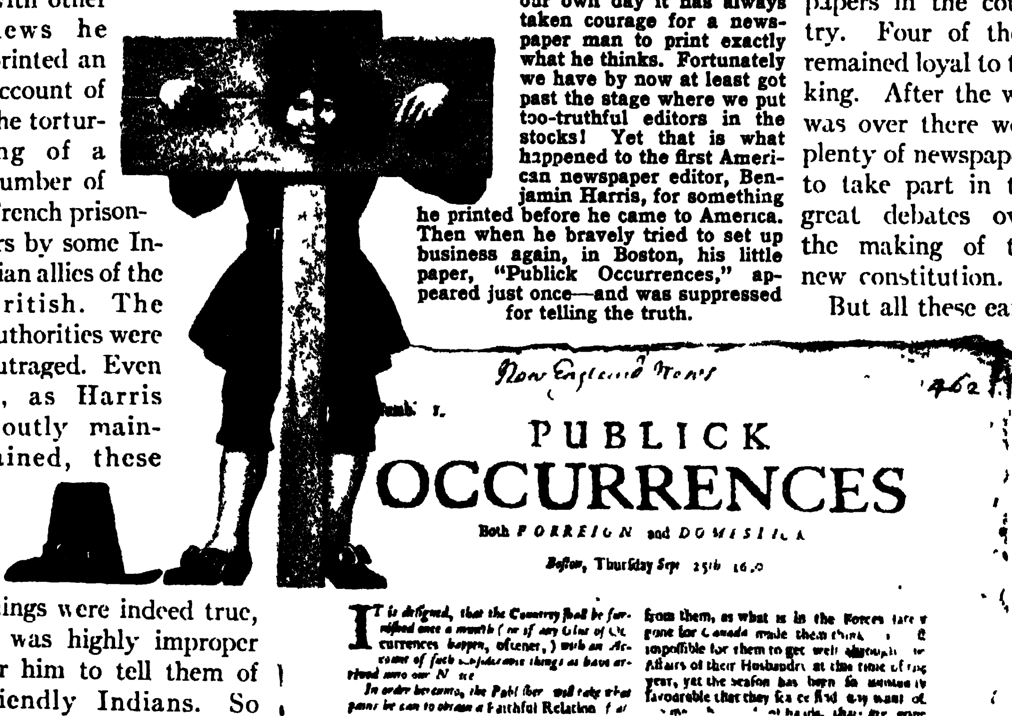
Photo by Braun et Cie

In the later Middle Ages, when the republic of Venice lorded it over the eastern Mediterranean and sent her bold traders even to China, there must often have been exciting news to tell the people at home. Should you not like to know what this man is reading from his paper? Is it news of a victorious sea fight, the announcement of a festival or an assembly, the proclamation of some decree of the ruling doge? Whatever it is, he has gone to a spot where he is certain to find people gathered—to no less a place than the great cathedral of St. Mark, which in that age of faith was at the very heart of the city's vivid, colorful life.

planning to celebrate a Thanksgiving of their own, how a man had committed suicide, how two children had been stolen by the Indians near Deerfield, and how smallpox was abating in Boston. But once again its publisher told the truth too plainly. Along with other news he printed an account of the torturing of a number of French prisoners by some Indian allies of the British. The authorities were outraged. Even if, as Harris stoutly maintained, these things were indeed true, it was highly improper for him to tell them of friendly Indians. So "Publick Occurrences" was suppressed, and never saw the light of day after that first issue of September 25, 1690.

It was Postmaster John Campbell who published (1704) the first regular newspaper in the colonies. The postmasters at the various colonial ports were in a very good position for getting news from the old country—and of course that was the news that everyone wanted to hear. Campbell made up his "Boston News Letter" almost entirely of items gleaned from papers and bulletins sent by ship from old England. Sometimes the "news" would be six months old, but it was new to its readers and that was the main thing.

The "News Letter" was a poor paper, but for fifteen years it was the only one the colonists had. In 1719 Brooker, who followed Campbell in the Boston post office, began to publish the "Boston Gazette,"


PUBLICK OCCURRENCES

Both FORREIGN and DOMESTICK.

Boston, Thursday Sept. 25th 1690.

From the beginning down to our own day it has always taken courage for a newspaper man to print exactly what he thinks. Fortunately we have by now at least got past the stage where we put too-truthful editors in the stocks! Yet that is what happened to the first American newspaper editor, Benjamin Harris, for something he printed before he came to America. Then when he bravely tried to set up business again, in Boston, his little paper, "Publick Occurrences," appeared just once—and was suppressed for telling the truth.

Photo by New York Public Library

which was so much better than the "News Letter" that it put its competitor out of business. As the war clouds of the Revolution began to gather, newspapers multiplied, and when the storm at last broke there were thirty-seven newspapers in the country. Four of them remained loyal to the king. After the war was over there were plenty of newspapers to take part in the great debates over the making of the new constitution.

But all these early newspapers could be distributed only as fast as a horse could travel. So when the news arrived it often was not very fresh. It is easy to see, then, what a difference the railroads and telegraphs made to the newspapers. Now the latest news could speed along the wires to the publishers' offices, and from there be spread at once to people all over the land. That was what made us into a newspaper-reading nation. Gradually the West was opened up, and settlers moved there from east and south and from far across the sea. And everyone wanted to keep in touch with the life of the nation which he was helping to build.

When Penny Papers First Appeared

But even then only a part of the people could have afforded to have the news if it had not been for the fall in the price of paper and the improvements that came about

Photo Copyright Detroit Publishing Co

The most famous printer in America during colonial days was Benjamin Franklin, who in spite of his great fame in many other fields liked to sign himself "Benjamin Franklin, Printer." Here he is hard at work in his Philadelphia printing shop, from which came not only the "Pennsylvania Gazette," most widely-read newspaper in the colonies, but also the famous "Poor Richard's Almanac" and many other good things.

in the processes of printing. After those changes it was possible for everyone to have all the news for one or two or three cents a day.

Of course the improvements came about gradually. A little more than a century ago the type for the newspaper had to be set, and the whole paper had to be printed, by hand. The type was laid, one page at a time, upon a flat bed, and was inked by hand with a roller. Next a sheet of paper was laid upon the inky type, and the top of the press was brought down upon it. That printed page was then carefully lifted off and laid on another form, to be printed on the other side in the same slow way. In other words, printing had not moved very far beyond the methods of its first inventors. With such slow processes a paper could hardly reach beyond a circulation of a thousand copies a day.

The Ancestor of Our Modern Presses

The first big improvement came when a German named Friedrich Koenig (kû'nĭK) invented the steam cylinder press, at the time when we were fighting our little War of 1812. With this invention type forms of two pages at a time could be laid on a flat bed and moved back and forth by steam power under a heavy revolving drum which carried the paper Sheets of paper were fed to the drum by hand from a table at one end of the press Such a press could print eleven hundred copies in an hour.

Guarding a Great Invention

John Walter, of the London "Times," was the first publisher to take up Koenig's invention. Now Walter was afraid that his men would object to the new process because it would rob some of them of their jobs. So one night in November, 1816, the "Times" pressmen were told to hold back the paper until delayed news came in from the Continent. That was a common enough order in those days when news had to cross the Channel by sailing ships; so the men thought nothing of it. At six o'clock in the morning Walter came in and told the men that the "Times" had already been printed by steam in another building. He urged them to take it peaceably, for, as he said, the change had to come. And he promised all the men full wages until they found other work. To-day, thanks to the very invention which at first saved so much labor, thousands of men are employed at the presses where only a score

were employed before. For in the long run that is always sure to be the result when labor-saving machinery is brought into an industry.

800,000 Pages an Hour!

The next big improvement came with a process for making metal plates of the type forms. These plates were bolted to cylinders and the cylinders were passed over "webs" of paper which rolled automatically off great spools. On the electrically-driven web presses of to-day, our great dailies can run off 100,000 eight-page papers in an hour.

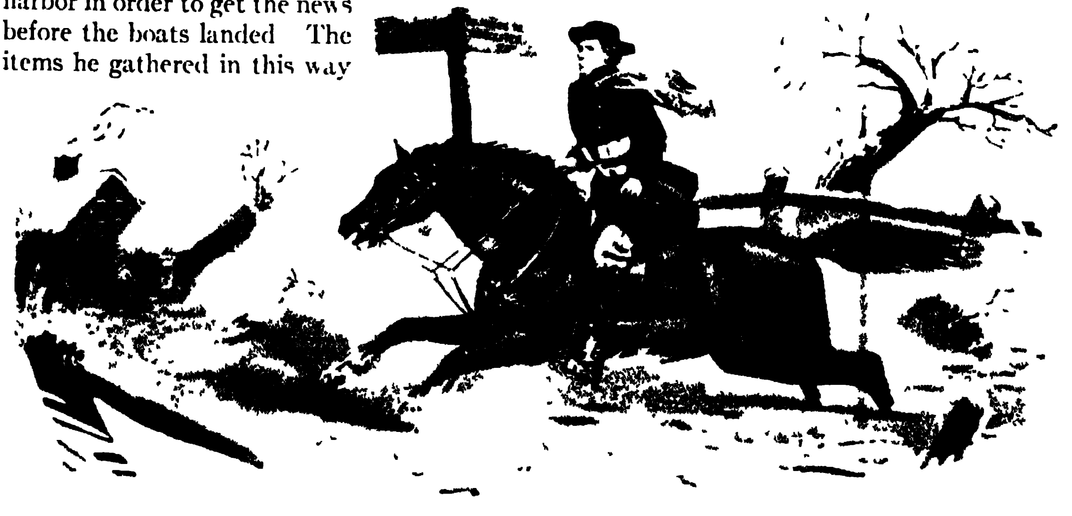
Next Otto Mergenthaler of Baltimore invented his linotype (līn'ô-tīp) machine in 1886. This set type by machinery instead of by hand. The operator of one of the machines could do the work of five of the men who used to set the type by hand, for there was no more tiresome picking up of every tiny letter and still more tiresome sorting of the used type after the article had been printed.

And then the editorial departments of the great dailies put their heads together to improve their ways of gathering the news. For that was a most expensive business. Every newspaper was spending enormous sums in trying to be the first to get hold of the news. Way back in 1811 Samuel Topliffe had started going out in his own sloop to meet the ships coming into Boston harbor in order to get the news before the boats landed The items he gathered in this way were put into "Marine Books," which newspaper men could consult in the coffeehouse. Later Topliffe had correspondents in the most important European cities, and the news thus gathered for him was sold in the shape of "letters" to regular subscribers to his news service.

Cub Reporters of Other Days

Two newspaper men of New York met incoming boats in a fast schooner, the "Journal of Commerce," from which they would signal the news to a semaphore posted on the highlands of Sandy Hook. The semaphore then passed it on by signal to Staten Island, where the editors could get it well ahead of rivals who waited for the landing of the boats. Another New York newspaper man got the news from Cunard liners coming into Boston from Liverpool and hurried it down to New York by a galloping pony express. He was also enterprising enough to install a carrier pigeon service from Albany to New York, for the purpose of getting the governor's annual message ahead of all his competitors. Naturally all such schemes cost a great deal of money, and only the larger papers could afford them.

With the coming of the telegraph and the ocean cable the publishers were put much more nearly on a level in the matter of getting the news. But there was such a scramble to get messages through to all



This is not Paul Revere, but merely a newspaper reporter in the old days dashing about to gather his news, or perhaps to distribute the printed papers. And now our news is gathered by radio or telegraph, and the papers distributed, sometimes, by airplane!

By Ewing Galloway, N. Y.

Here at the U-shaped Copy Desk of a large city daily the work of reading and correcting the news articles and writing the headlines for the next issue is going on. The "slot man"—facing the camera—is in charge.

the various papers that the wires were crowded beyond capacity. Something had to be done. So in 1893 sixty-three newspaper men decided to band themselves together in what they called the Associated Press. To-day many hundreds of newspapers belong to the association, and receive the news sent by its correspondents stationed in every corner of the globe. Radio, cable, telephone, telegraph, and post pour in the items in a never-ending stream. The association leases thousands of miles of wire, and may send in news from as many as two hundred foreign points in a day—and from thousands of points inside the nation. Its reports have earned a reputation for being reliable; and of course they must never take sides, for then they would no longer be of use to all of the members alike.

Our Modern News Carriers

Nobody makes any profit from the Associated Press. The members divide its expenses—many millions a year—among themselves, and each paper pays according to the amount of service that it takes. The United Press, which was established in 1907, gives the same kind of service as the Associated Press, but its customers pay a fixed rate and it is run for profit. Many papers get their news from both services, and the big city dailies have special correspondents of their own besides.

What Do A.P. and U.P. Mean?

So that is what those familiar letters A.P. or U.P. mean at the head of a dispatch. They are the initials of the two largest news-gathering agencies in the United States. We have others as well; and there are famous ones abroad, such as Havas of Paris, Tass of Moscow, and Reuter's (roi'tẽr), of London, the oldest of all, for it was established by a German, Julius Reuter, in 1849. If it were not for all these agencies only the biggest of the dailies could afford to give us much of the news.

But even then, no newspaper could afford to sell its news so cheaply if it were not for the money made on advertising. That is what every paper relies on to pay its expenses. And since advertisers will pay more for space in a paper that has a large number of readers, every paper tries in all sorts of ways to please the public and so increase its circulation.

Right here it must make a choice. By printing lurid accounts of crime and all

sorts of disgusting scandal it may appeal to a large number of readers, but they will mostly be of low intelligence and ignorant, so they will be unlikely to have much money to spend on the goods they see advertised. In order to gain a better class of reader, more intelligent and refined, a paper must fill its columns with something besides the filth one sees in the so-called "yellow journals." Its circulation may of course be smaller, for there are fewer intelligent people in the world than there are of the unintelligent. But as a rule the intelligent people will have more money, and so the paper they buy can usually charge more for its advertising than many a paper with a larger circulation.

Now let us imagine that you are an ambitious young reporter on one of the morning papers in any large city. You want to get ahead as fast as you can, and are willing to do your best on every "story" that is assigned you—for to a newspaper man any article is a "story," no matter how close to fact and how far from fiction it may be. We will suppose that the city editor, who is responsible for the gathering of the local news, has sent you to "cover" one of the police courts. You take your place in court and listen to case after case, few of them very interesting. But finally a taxi driver named Tommy Jones is put in the stand and testifies that the night before he was held up and robbed of ten dollars, all the money he had. Later in the night he was held up again by the same man and robbed of his cap, his coat, and his taxi. And later still, as he was riding on the back seat of a friend's taxi to make his report at police headquarters, he was dragged out of the taxi in order that the selfsame bandit might use it to make his escape.

Facing Tommy in the court is another man. From the photographs in the "rogues' gallery" at police headquarters Tommy has picked out this man's photograph as being that of the persistent thief. But the man's sister upholds his alibi when she confirms his statement that he was sitting quietly at home while Tommy was meeting his adventures. So, rightly or wrongly, the man is set free, and Tommy is short his money, his taxi, and his coat and cap.

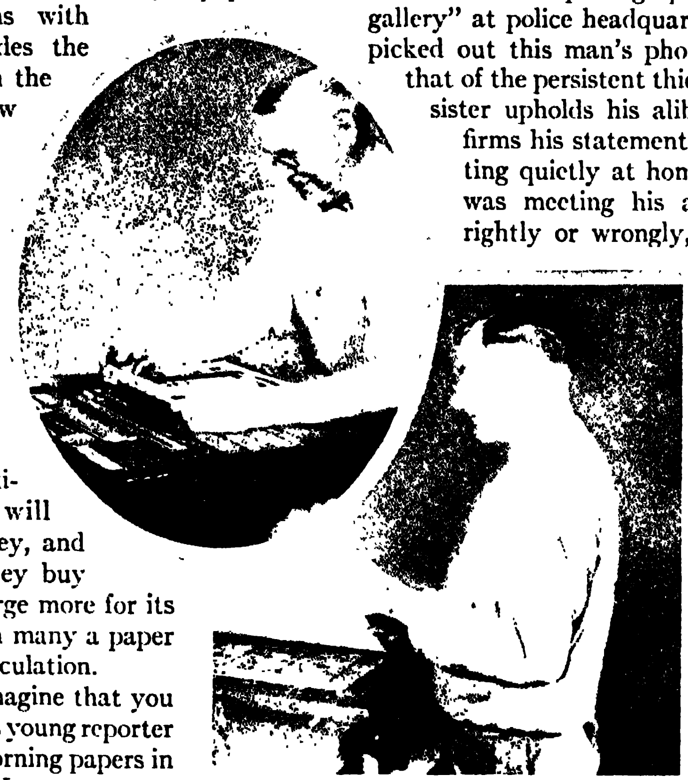


Photo by Chicago Tribune

The jolly man in the oval is composing, or "making up," a sheet of newspaper. It is careful work to display the news, not to mention the features and the advertisements, so as to make just the right effect, with all the news, according to its importance, given just the right place on just the right page under just the right-sized headlines. In the square a man is removing from the form, or page of type, the mat or matrix. This mat will give its impression to the great curved metal plate from which the page will actually be printed.

Now you think that in the trials of Tommy there is material for a story that will make interesting reading to a good many persons. So you hurry to the newspaper office and write it up in your best vein; and when you turn it in to the city editor you have made enough "copy" of it to fill a column in the paper. You will not see it again until the paper comes out, but you very much hope that it will not be thrown into the waste basket, cut down to fill only an inch or so of space, or tucked away in some obscure corner of the paper. And meanwhile the city editor looks it over, marks on it the amount of space it is to have, the sort of heading that shall be printed above it, and where it is to come in the paper, according

Day and night these huge presses whirl, turning off many millions of newspapers every day in the United States alone. It takes between five and six million tons of paper every year to feed them. Probably much of what goes into our newspapers is not worth the noble spruce forests we grind into these tons of paper. But a really fine newspaper is one of the bulwarks of our modern civilization.

to the plan which the managing editor has mapped out for that edition. Next a copy editor takes your story, cuts it down or expands it, according to orders, and gives it a heading that will attract readers. And then the trials of Tommy Jones are shot through a tube to the composing room, where a linotype operator will set the story in type.

The Magic of a Linotype

How good old Gutenberg, the inventor of printing with types, would open his eyes at that linotype! Sitting at a keyboard rather like the keyboard of a typewriter, the operator pushes down a key marked with a given letter, and down comes a little brass mould of the letter he wants. It takes its place on a line with other moulds of other letters. With the help of his machine he summons mould after mould to its place in the line, all of them arranged neatly in words, with spaces between. When a line the width of a newspaper column has been filled up in this way, melted lead from another part of the machine is poured into the moulds, and then the whole line of lead type will be automatically cast in the lead. Now you can see where the machine gets its name. The moulds go back into place to be used again and the operator keeps on making lines of type, or "slugs," until the story of Tommy Jones and his midnight mishaps is finished.

Those slugs will take their place in what is called a 'form'—or hundreds of lines of type arranged in columns with headlines for each story, just as on a printed page. But though the type is all perfectly arranged you could not print the thousands of copies of your paper from this form. For one thing the type slugs might fall out, but worse than that, the form is flat, while the press is in the shape of a cylinder. No, the actual printing must be done from hard and solid metal, cast to fit your curved cylinders.

How a Stereotype Is Made

So, with the rest of the form, your story goes to the stereotyping (stĕr'ē-ō-tīp') department. There a sheet of soft, moist paper about the thickness of thin cardboard

is pressed down over the type until it takes the exact mould. Then this paper mould—called a matrix (mā'trĭks) or mat is dried and curved to fit the rounded side of the printing press. Next the intelligent autoplate machine takes the paper mat, and using it as the pattern, makes plates from it out of the molten metal that flows over it. The curved plates, which carry the type from which the paper is actually to be printed, come out at the rate of four a minute.

Speed is everything in getting out a paper nowadays. So almost in the twinkling of an eye, the plates have been bolted into place, an electric starter has set everything whirring, and the pages are running through the enormous press. The type is kept sprayed with ink automatically, and the paper is automatically fed into the press from a huge spool at one end. And at the other end out drop the papers, all cut, folded, and counted, at the rate of hundreds to a minute. The machine seems able to do everything but read them!

By now it is between one and two o'clock in the morning. In the mail room the force is waiting with wrappers all printed with the names of subscribers who get their paper by mail. The mail sacks yawn, ready to catch the addressed packages that will go to the trains in the motor trucks that are backed up at the door. Trucks will take other bundles that are to be sent by express or to go to the various news stands over the city. Often the papers to be sold in districts close to the plant will be given out to a clamoring throng of newsboys, each one of them eager to get the first batch and be the first on the street. There he will shout the headline call that the man in charge of the distributing has given to them all, to help them in selling their wares.

But the "big" news is not what you are interested in to-day. You want to know what happened to your story of Tommy Jones. The instant your paper appears you seize it and look to see. You cannot expect it to be on the front page, which is given over to important local and foreign news. Neither do you expect to find it on the next best pages, the second and third. But you are glad to see it on the back page, which in your particular paper always carries interesting local news. It is at the top of the middle column, and has been allowed half a column, with the catchy title, "Jehu Plays Tag with Thief."

"Good enough," you say to yourself, and eat your breakfast with relish.

This rotary press turns out newspapers for the people of Reading in England. On large presses of this type 40,000 newspapers of thirty-two pages each can be printed, folded, and assembled, ready for delivery, every sixty minutes. Andrew Campbell of Jersey City did more to work out the modern rotary press than did any other one man. It first went into operation about 1875. To-day democracy as we know it could hardly exist without this device for spreading information among the people

British Official Photo

Reading Unit
No. 8

WHAT A POSTAGE STAMP WILL DO

Note: For basic information not found on this page, consult the general Index, Vol. 15.

For statistical and current facts, consult the Richards Year Book Index.

Interesting Facts Explained

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Summary Statement

Because we believe that the spreading of intelligent ideas makes a nation enlightened and progressive, the purpose of our postal system is not to do a driving business in postage stamps, but to pass valuable goods—and still more valuable ideas—as quickly as possible among the people.

Above, you will see the sort of thing that happens in the Dead Letter Office. These particular stacks of letters are from people who wanted to know difficult words in cross-word puzzles and who have sent their questions addressed to government bureaus which do not exist. Above to the right are men sorting letters into pneumatic tubes. These tubes are shot by compressed air at lightning speed through iron pipes to various post office stations in large cities. A single tube will carry as many as six hundred letters. The scene at the lower right is laid in the "nixie" section of the Chicago post office, where the older and more experienced employees spend a great deal of time and effort making corrections on misdirected letters. They must wonder how there can be so many stupid and careless people in the world. Below is an inside view of a mail train, where men are sorting letters into bags that will be put off when the train stops, and then start off in a dozen different directions without delay.

Photo by Keystone View Co.

When mail bags are put off trains, planes, or ships, they are usually loaded into trucks and taken to the post office. There the mail is sorted according to the zone, street, or route address. In big cities a letter is greatly speeded if the address includes the zone number, for then the employees at the central office know at once to what branch office the letter should go for its final sorting. The Post Office Department is always trying to make service swifter. Mail carried by plane, for example, may be just dropped for pick-up at spots where there are no landing fields. And helicopters are beginning to replace trucks for delivery between post offices and airports.

Photo by Luxembourg Museum

In the time of the ancient pharaohs of Egypt royal messages were carried by slaves. All was well for the messengers who brought good news, for then they were rewarded with gifts; but woe unto those who brought evil tidings. For like the slaves in the picture above they were instantly put to death.

WHAT *a* POSTAGE STAMP WILL DO

The Story of What Happens to a Letter We Drop into a Box to Start on Its Travels around Half the World

DID you ever start a neighborhood post office inside a hollow tree in the back yard? You cut a slit in an empty cigar box, and everyone who was in the secret posted his letters in the box, which you kept carefully hidden inside the tree. And whenever you visited your post office, you wandered toward it quite as if by accident, and after a hasty look around, you snatched the box out, opened it to see if by any luck it held a letter for you, and then hurried quickly away. You went for your mail eight or ten times a day, if the weather was good, but most of the time you had the trip for your pains.

Now your post office was all a make-believe, as you knew well enough; and yet, strange as it may seem, a good many of the world's post offices have been in just as strange places as your hollow tree. For it is not very long, as history is reckoned, since all the private letters that anyone ever sent had to be carried by hand or left in some safe place to be called for. As lately as 1849, when people rushing for gold in California took the long, long route by boat around the Horn, they used to leave letters for their friends at home in a strange post office down at the very tip of the world. It was a strong wooden keg, wedged between two big rocks and treated with a coat of tar to make it waterproof. All a man needed to do was to lift its iron lid, which worked on leather hinges, and drop his mail inside, ready to be picked up by any passing ship bound in the other direction.

It was at the Cape of Good Hope, on the other side of the world from the stormy Horn, that English and Dutch voyagers, before the land was settled, left packages and letters under big stones on Table Bay. Some of those old "Post Office Stones" were found

not long ago by men digging at Cape Town. There they had lain for many a year, but not long enough for their quaint inscriptions to be worn away. For cut into their faces was the invitation to "Look hereunder for letters."

The Post Office at Ash Hollow

Our own new land saw makeshifts just as queer. By a spring in Ash Hollow on the North Fork of the Platte River, there used to stand an abandoned cabin that once had been the home of trappers. There pioneers bound for the West in 1846 used to leave hundreds of letters with the request that the next traveler eastward should drop them in the first post office on his route. It is hard to say where that post office was, but if he carried them all the way to Chicago he could leave them there in a post office that the government had established back in 1831, when the postmaster had nailed to the wall a row of old boots to serve as letter boxes.

Now all this will show you that the world's postal service, in spite of its tremendous size, is still very young. None of those old post riders, who traveled with such effective speed throughout the Persian or the Roman empire, ever took any but government dispatches. A private message had to go by private messenger, as one may see from various passages in the Bible; for instance, when the apostle Paul, though himself a Roman citizen and entitled to all the privileges that belonged to him as one, nevertheless says again and again that he is sending his epistles by the hands of friends.

And yet on the government's business those old couriers were so efficient that our very word "post" has come to us from the Latin "positum," the name for the relay stations that the government kept for its messengers along the Roman roads.

Of course all this magnificent organization was swept away with the fall of the empire that had set it up, and for many a century any message that was urgent enough to be sent at all had either to go by special messenger, riding at great expense over the dangerous roads, or to take its chances in being passed from hand to hand by travelers whose business happened to take them in the right direction. Finally the big universities and the guilds of merchants set up postal services of their own.

By the close of the Middle Ages business had increased so much and people had come to have so much to say to other people at a distance that a remarkable family of hereditary postmasters-general, known as the counts of Thurn and Taxis, set up a fine mounted courier service between the chief cities of Europe. One of them, Francis von Taxis, founded the Imperial Post of the emperor Maximilian; and it is interesting to see that he was powerful enough to insist that his couriers should carry the letters of private persons as well as those of the emperor and his officials. In 1516 he established what was probably the first letter post; it ran between Berlin and Vienna.

When Posting Letters Was a Crime

It was some time before anyone had the enterprise to start the same sort of venture in other countries. To be sure, Henry VIII had a royal post in England, but it carried only court messages, and the system established by his masterful daughter, Eliza-

The passengers on this Royal Mail coach are not so carefree as we who travel in a Pullman. Besides putting up with the bumping, the cold and wet, and the spoiling of their beautiful top hats, they know that it may not be long before the coach is stuck and they will have to get out and push!

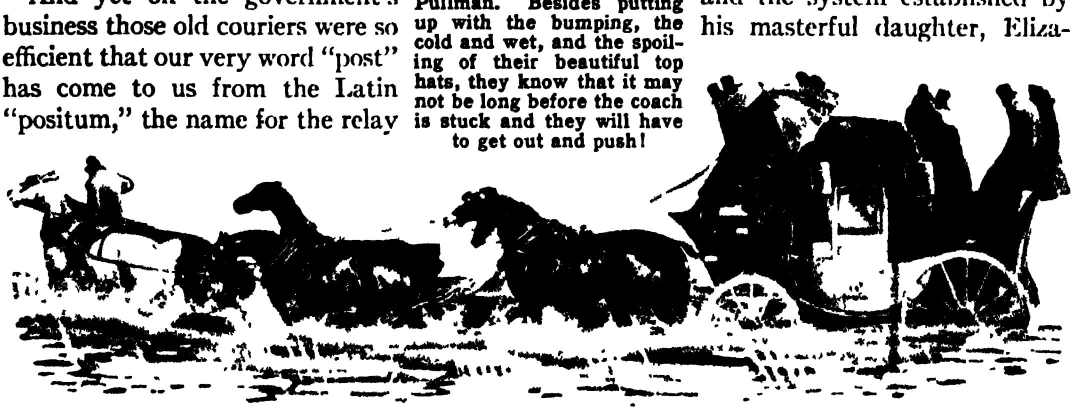

Photo by Rischgitz

Photo by First National Bank, St Joseph, Mo

Try to imagine that you are living in a little Missouri village in the sixties. One small house serves as store, post office, and town hall. You are waiting there for the Pony Express. Perhaps the rider has been held up by Indians! No, there he comes and, pausing barely a second, he gallops off again in a cloud of dust.

beth, did no more. Indeed, under her reign the writer of a private letter directed outside the country was at once suspected of plotting against Her Majesty, and anyone caught carrying one was thrown into prison. Naturally there was not much demand for a postal service under such conditions, and of course news was hard to get.

England's First Public Mail Service

But things quieted down by and by, and Thomas Witherings, a Scotsman, organized a system in the first half of the seventeenth century by which private persons might send mail at their own expense. Toward the close of the century the first armed mail coaches went into service to carry His Majesty's mail. They put a stop to the mail robberies, which had grown so common that bank notes and other valuable papers had to be torn in half and each half sent separately. In 1840 Great Britain set an example to the rest of the world by adopting the plan of Sir Rowland Hill and cutting her letter rate to two cents an ounce. At the same time she introduced the postage stamp, which meant that the sender paid the postage.

And meanwhile the colonists had found that they too had things to say to their friends at a distance. As early as 1639 it had been decreed by the general court of Massachusetts that "Richard Fairbanks his house" in Boston should be the headquarters for foreign mails. He was to see that letters were dispatched overseas or that they reached the hands of the colonists for whom they were intended on this side of the water—and on every letter he was to have the fee of a penny. He could hardly have grown rich, for missives were few and far between

But even that hit-or-miss handling was better than the common practice, by which a ship's captain would hang up a bag for letters in some tavern or coffeehouse several days before sailing, and then dump its contents on some inn table when he reached port. There the letters would be looked over by all comers, and at last, all thumbed and greasy, they might reach the hands of the persons to whom they were addressed.

When Every Farmer Was a Postman

In Virginia a law of 1657 required every plantation owner to pass on all mail to the plantation next his; and so a letter journeyed from hand to hand until it reached the owner.

If any man was careless in this duty, he was fined 350 pounds of tobacco—which meant a tidy sum of money in those days. It was not till the close of the century that the king appointed a postmaster-general for the colonies.

Some sixty years later a very able man was found to do the work. For sixteen years he had been giving the little city of Philadelphia an excellent postal service--and distributing his own newspaper, "The Pennsylvania Gazette," in this way. Now that man's name was Benjamin Franklin, and for years to come he was to organize the mails for those bustling young colonies, and put the service on a sound paying basis. This was a worrisome business in those days, when it took a letter as long to cover the thickly-wooded, sparsely-settled country between New York and Georgia as it would now take one to travel from New York to Shanghai. But Franklin opened up new routes everywhere, and improved the old ones; and when the Revolution came, the colonies could get messages back and forth quickly.

The Wit of Ben Franklin

Before the Declaration of Independence Franklin had been privileged to send his own mail free, simply by endorsing it "Free. B. Franklin." But after the Declaration the good old patriot thought he could improve the order of those words, and he endorsed all his mail "B. Free Franklin."

After the Revolution, the story of our postal system is the story of the growth of our country. And a thrilling story it is—a story of bravery and hardship and of unfaltering devotion to duty. Perhaps there is no more stirring chapter than the tale of the Pony Express, which set out to rush the mails from the end of the railroad, at St. Joseph, Missouri, west to San Francisco.

The Pony Express

The slow-going Overland Stage had long been doing the work in a steady, plodding fashion, but a firm of business men finally decided that money was to be made by running a quicker service So they bought 420 horses and hired 400 station men and 125 riders, every one of them an excellent horseman and a crack shot. At seven-thirty on an evening in April, 1860, a rider at St. Joseph leaped into his saddle as the shot of a cannon announced the first run of the Pony Express. He was dressed in a buckskin shirt, cloth trousers, and a slouch hat, and carried a brace of pistols at his belt. He galloped down to the ferry, which put off the instant his horse's hoofs struck the floor, and soon he was across the yellow Missouri and away in a cloud of dust.

Out through the night he rode, stopping for two minutes every ten or fifteen miles in order to get a fresh mount. At last, at the end of his run of seventy-five or a hundred miles, he handed the bag at his saddle horn over to a new rider who went pounding on with it. On that first trip the bag contained dispatches of Eastern news for the San Francisco papers, forty-nine letters and five telegrams. On each piece a fee of $5 had been charged, besides the regular government postage. Later the rate was reduced to $2.50.

Night after night and day after day, over plains and steep moun-

This old mailcoach has seen history in the making. It was captured by Indians, and cost General Howard a fierce fight to get it back. In the same year General Sherman used it on a tour of inspection, and later it carried President Garfield and his successor, President Arthur.

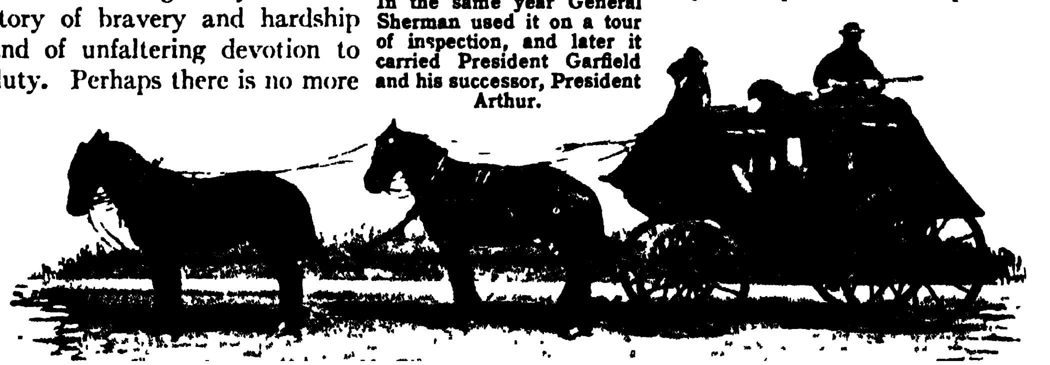

Photo by Northern Pacific Ry.

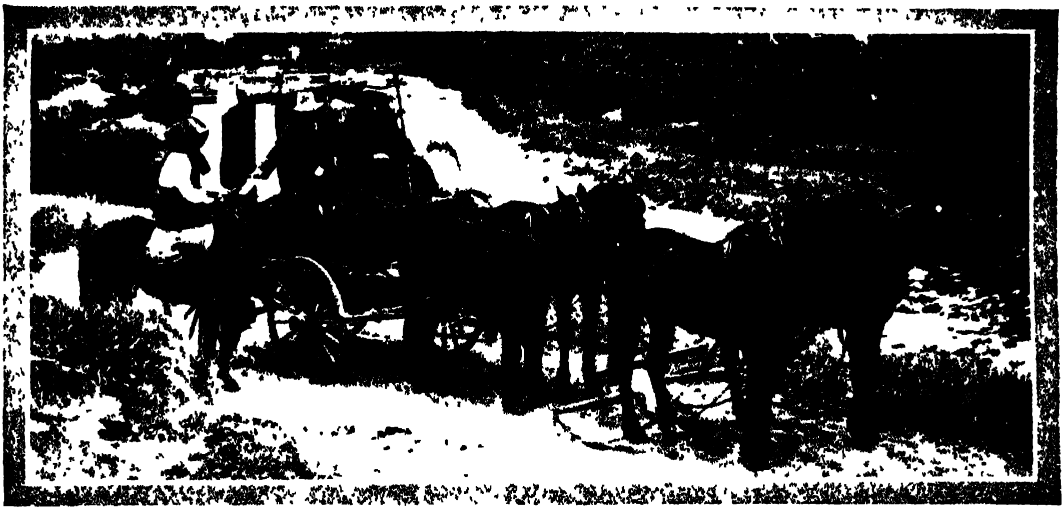

Photo by Commonwealth of Australia

The woman in this picture does not bother to wait for her mail at a post office. She just rides out along the road and stops the mail carrier. This Royal Mail coach was lately in use in a part of New South Wales.

tain trails, that first Pony Express flew west, without ever a moment's stop for the cheers and speeches that greeted its passage through every settlement. At Sacramento the California legislature adjourned in its honor - but horse and rider kept straight on to the steamer "Antelope," which was waiting on the Sacramento River to take them to San Francisco. News of their arrival had been sent ahead over the short California telegraph line, and when the weary man and horse reached the end of their journey late that night, they were escorted to the post office by a band, by all four of the town's fire engines, and by most of the population. The 1,966 miles had been covered in less than eleven days

The Record Ride of the Pony Express

But that was not the record for the Pony Express. When President Lincoln was first inaugurated, it carried a copy of his address out to the western coast in seven days and seventeen hours. The Pony Express had a share in holding the Union together during those troublous times. Its riders took their responsibilities very seriously. They were not only superb horsemen; they were brave men, who faced danger and death at the hands of the hostile Indians along the route. One day when "Pony Bob" Haslam found a relay station burned and his relief killed by the Piutes, he kept on riding for 380 weary, dangerous miles. For the mails had to go through!

Buffalo Bill Outwits the Bandits

Some of those riders for the Pony Express won their way to fame. When he was only seventeen, "Buffalo Bill" Cody was given a large sum of money to carry over the route. He learned that a party of bandits had got wind of the fact, so he made up a "dummy" package which he fastened to the usual place on the saddle horn, while he hid the package of money under the saddle. It was lucky that he did! At a lonely spot in the road, up rose two masked bandits and with their pistols drawn demanded the mailbag. Bill made a great show of reluctance and undid the sack. Then suddenly rising in his stirrups, he threw it squarely in the face of one of the bandits, and giving the other a "side swipe" with the hoofs of his mount, he was off like the wind to the next station, where he safely delivered his money.

Such were the brave beginnings of our postal service—now the biggest business in the world. The lumbering mail coaches—with green bodies, red wheels, and the words "United States Mail Stage" painted in yellow beneath a great eagle on the panel—ceased to appear along the main routes of the young republic. To-day hundreds of mail cars, each one manned by a crew of expert clerks

who can sort the mail at lightning speed, carry the precious load to every corner of the land at the rate of forty or sixty or ninety miles an hour. The letter that took twenty-four hours to go from New York to Philadelphia now can cover the distance by airplane in less than an hour. The 75 post offices and 2,400 miles of post road that served the country in 1789 have now been increased to tens of thousands of offices and hundreds of thousands of miles of railroad - to say nothing of thousands of miles of airways and of rural delivery routes. Back in the 1830's the government had its hands full trying to persuade the infant railroads to carry the mails at night. It was not considered at all the thing for trains to travel after dark. To-day Uncle Sam's messengers never stop, but rush on night and day. For the mails must go through!

It was not till 1883 that the United States followed England's lead and reduced its postal rate to two cents an ounce. At first the rate had been very high and was paid by the man who received the letter. A single folded sheet, without any envelope, cost six cents for thirty miles in those days and the farther it went and the bulkier it was, the more it cost. A man in Baltimore might easily spend twenty-six cents to get a letter from Boston. No wonder people wrote twice across the page, the second time at right angles to the first lines of writing. But by 1847 the United States, too, had introduced the postage stamp, and then the sender paid for the letter—and could, with a clear conscience, make it as long as he liked.

Photo by Keystone View Co

Skates, skis, snowshoes, bicycles, automobiles, and airplanes carry the postman. Here is one, however, who still uses the good old-fashioned method. He walks.

There is no place in the world where three cents will buy you so much as at the post office. For that modest sum you can pour your whole heart out on paper and send it halfway round the world. Scores of persons will handle it, swift trains will speed it along by land, and laboring steamers will take it over the sea. It will be weighed and fingered and counted. And yet it will travel all those thousands of miles more safely than if you were carrying it in your own pocket. And out of all the millions of people it passes on the way, it will seek out just the right person and bring its message only to the eyes for which it was intended.

Of course there are times when things may go wrong usually because you have not addressed your letter clearly and correctly. But if your missive strays it will be sent, first of all, to the Directory Service, where a staff of trained clerks minister first aid to letters in distress. They take great pride in their skill, and are proud to find the Miss Mary Brown to whom some wag has sent a letter addressed to 20 West One Minute Street, New York City. Can you solve that riddle of the postal clerk? The answer is that Miss Brown lived at 20 West Sixty-second Street. Often the tangle can be straightened out and the hapless letter sent on its way. But this service on "nixie" letters, as they are called, costs the government a pretty penny. In New York City alone it mounts up to five hundred dollars a day.

The Mystery Letter from China

Once upon a time a letter arrived at San Francisco, having come from China, addressed to "Mrs. Hop-Top, Pekin Street, America." The post office sleuths finally delivered it to Mrs. Apthorpe, in Beacon Street, Boston. It was from a

former Chinese servant, whose English was faulty.

If the case of the letter is hopeless, it goes to the Dead Letter Office, where millions of letters and hundreds of thousands of packages are received every year, and in them millions of dollars in valuables. And all because a good many people have been careless! At the Dead Letter Office the mail is opened, and if the address of the sender can be found the letter or parcel is returned to him. Letters and parcels of no value are destroyed, but steps are taken to trace the senders of checks and money orders. Everything of value that remains is put up for sale at one of the public auctions held four times a year by the Dead Letter Office.

Since 1878 the sending of mail from nation to nation has been made a good deal easier by the International Postal Union. Nearly all the countries in the world belong to it, and every three years send representatives to the headquarters at Berne, in Switzerland, where all matters of international postal business are discussed. We have made an agreement with certain foreign lands which allows us to send letters into those countries at the same rate we pay on letters that go only to the next town. But the foreign rate in most cases is five cents an ounce.

It was in 1918 that Uncle Sam began to send his mail literally on the wings of the wind. In May of that year the first air-mail line was opened between New York and Washington. At first the Post Office Department used its own planes and pilots. But when the service showed that it would be a success, contracts were let to qualified firms with reliable pilots—in just the way that contracts have long been let to railway and steamship companies. To-day air lines connect all the great cities of the land, and a letter can travel from coast to coast in a few hours. It can even be sped by air all the way to Argentina, and reach there in a few days instead of seventeen. New York is now in closer touch with Buenos Aires than it was with Savannah not much over a century ago. And in the air-mail service there is still need for the same steady nerve and cool daring as in the days of the Pony Express.

[illegible]

The mail you see being loaded on this great airliner has been brought to the airport by truck Now a moving belt is carrying it up from the ground to the door of the plane. It takes only a moment.

No wonder the postmaster-general is an important man, and sits in the president's cabinet! Not only does his organization handle a third of the world's mail, with a million and a half letters pouring in every hour, but the post office department does a banking business as well. By means of a postal money order you may send money anywhere in the world. More than a billion dollars changes hands in this way every year. A postal note, costing five cents, will let you send any sum not over ten dollars. And if you want to start a savings account, Uncle Sam will take care of it for you—and pay you interest at two per cent. You may start your future fortune with as small a nest egg as ten cents.

In other ways the Post Office Department has constantly reached out in order to be of more and more use to the people. If the town or village you live in is not very tiny, the mail will be brought to your door every day by a man in uniform. Or if you live in the country, away from cities and towns, the Rural Free Delivery service will bring you your mail. Many millions of persons get their mail in this way every day.

How to Use the Postal System

If you have things of value to send, you may "register" them and feel sure that the government is taking extra precaution to make sure that they arrive safely. And if you are in a hurry to have your letter or

parcel reach its destination, you may send it "special delivery" by paying 13 cents extra. Then a special messenger will carry it to the person to whom it is addressed, just as soon as it arrives in the office to which it is sent. It is possible, too, to have Uncle Sam take charge of money collections, for an article may be sent C.O.D.—or "cash on delivery"—and then the person receiving it pays for it through the post office instead of paying for it direct.

In 1912 the Post Office Department went into the express business. Under the Parcel Post Act merchandise—known as "fourth class matter"—may be sent inexpensively from one end of the land to the other, and if it is valuable, it may be insured. Sixty per cent of the total weight of the mails is now parcel post—and that means that many people can afford to buy from a distance all kinds of goods that they cannot find at home. If a parcel post package is sent "special handling," it is speeded forward as rapidly as a letter. The parcel post and the postal savings bank we owe largely to Mr. Frank H. Hitchcock, who was postmaster-general at the time those services were installed.

The other classes of mail are: first class matter, which includes letters, postcards, or anything else that is sealed; second class matter, which includes newspapers and other periodicals; and third class matter, which includes books, pamphlets, circulars, catalogs, and engravings. All these different classes are sent at varying charges.

Now all this service costs money—a very great deal of money. In fact, it costs over $700,000,000 a year. And though in the same length of time the postal service handles close to 40,000,000,000 pieces of mail, it sometimes comes out behind at the end of the year, for to handle some of that mail is very expensive, and the loss on it may well mount up to $30,000,000 in a year's time. But that is not a matter that anyone worries about. Uncle Sam goes into his pocket and makes up the amount, and considers that it is a good investment. For from his point of view the purpose of the postal system is not that the government may do a driving business in postage stamps, but that valuable goods—and still more valuable ideas—may be passed about among the people as quickly and as easily as possible. For it is the spread of intelligent ideas, and not of wealth and luxury, that makes an enlightened and progressive nation such as we wish ours to be. The mails must go through!

Still another advance was made by our Post Office Department when in 1942 it joined with the War and Navy departments in establishing the V-Mail Service for communication with members of our armed forces. A system was set up by which a letter written on uniform authorized sheets was photographed on 16-millimeter film—15,000 letters to a roll—and sent overseas at top speed. At its destination it was printed and delivered in an envelope. Over 1,250,000,000 letters were sent in this way. The mails must go through! One is reminded of the singing words of the Greek historian Herodotus, who said of messengers in ancient Persia: "Neither snow nor rain nor heat nor gloom of night stays these couriers from the swift completion of their appointed rounds."

Here are two of the strange-looking planes that first carried the mail between Los Angeles and Salt Lake City.

Reading Unit No. 9

WHEN OUR WORDS TOOK WINGS

Note: For basic information not found on this page, consult the general Index, Vol. 15.

For statistical and current facts, consult the Richards Year Book Index.

Interesting Facts Explained

Early attempts to send messages over electric wires, 10–95-96

Morse makes an electric current carry messages in code, 10-96-97

The first message telegraphed from Washington, 10-98

Telegraph apparatus, 10–98-99

How photographs are cabled, 10–94

The "teletype" machine, 10–99

Two million miles of telegraph wires in the United States, and more than 2,000,000 messages over them in a year. 10–99

Things to Think About

What improvements have been made in the telegraph since Morse's day?

How can an operator in New York make the telegraph apparatus respond in San Francisco?

How did Joseph Henry help Morse?

How does electric current make a circuit in the telegraph Morse designed?

Picture Hunt

Name three of the instruments which make a telegram possible, 10 97

How does the Continental code differ from the Morse code? 10 97

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What is the simplest way to make an electromagnet? 1 486-87

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How are telegraph messages carried under the sea? 10-101, 106

Summary Statement

The telegraph is one of the most important ways of communication in modern life. When men found out how to make electricity carry messages for any distance in an instant, they made life more comfortable and much more interesting.

Photo by Western Union Telegraph Co

This picture crossed the Atlantic by means of a cable stretched along the ocean's floor. It is easy to understand how a cablegram can be "clicked" across, but cabling a photograph sounds like a miracle!

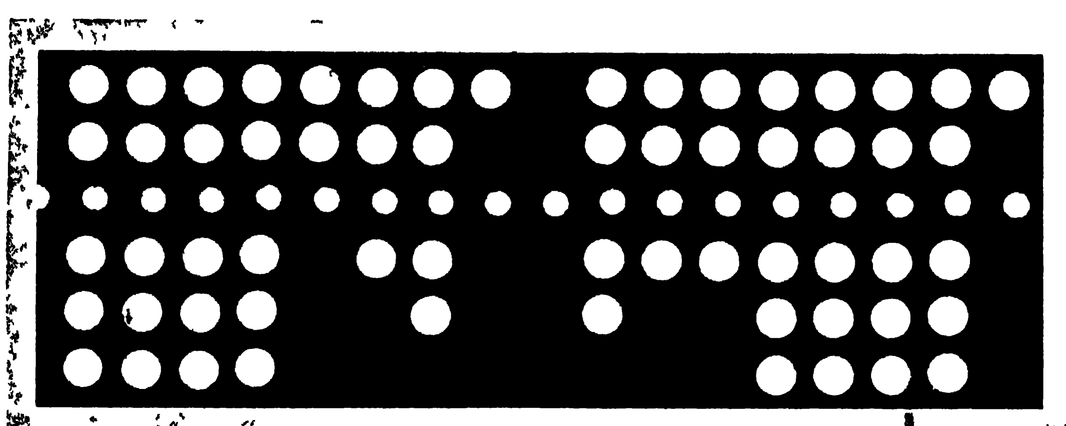


Photo by Western Union Telegraph Co

In 1920 the first photographs were cabled across the Atlantic. To-day such pictures are common in our newspapers, and we are no longer surprised to see in print a photograph taken thousands of miles away only a few hours before. The photograph is first mounted upon a turning cylinder. By means of a photo-electric cell—a device which produces an electric current when it is exposed to light the light and dark parts of the picture are turned into electric currents as the cylinder revolves. These currents are amplified, and then pass through telegraph wires, telephone cables, ocean cables, or are sent by radio At the other end the received currents are amplified again and used to illuminate a neon lamp which flickers with the variations in current. The neon light beam is focused on a film which is on a cylinder turning at the same speed as the cylinder at the sending source. The beam moves back and forth across the film, thus reproducing the original image. From this film a photographic print can be made, just as it is made from any film, or the picture may be reproduced for a newspaper A bit of such film is shown above.

This is the portrait of Samuel Morse, who brought about a new era in world communication. Below is his invention, the telegraph instrument that received the first telegraphic message: "What hath God wrought!"

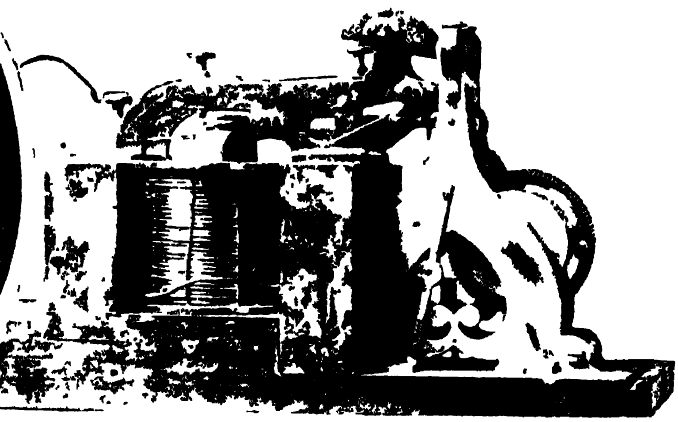


Photo by the National Museum

WHEN OUR WORDS TOOK WINGS

After All the Slower Ways of Carrying a Message from One Person to Another, We Finally Found Out How to Make the Electric Current Do It for Any Distance in an Instant

EVEN if he has no television set, a lover of baseball may watch a game as it is played a thousand miles away. He may go to a theater or newspaper office and see a kind of moving map that records every play as it is made And the news of many other happenings is brought to us almost before they take place. You would think it absurd if the morning newspaper did not tell you all the exciting events that had taken place in China a few hours before, and you are not even surprised when the paper prints pictures taken last night on the other side of the country. As for the telegraph boy, with his jaunty cap and his yellow envelopes, you perhaps see him so often that you never think about him at all.

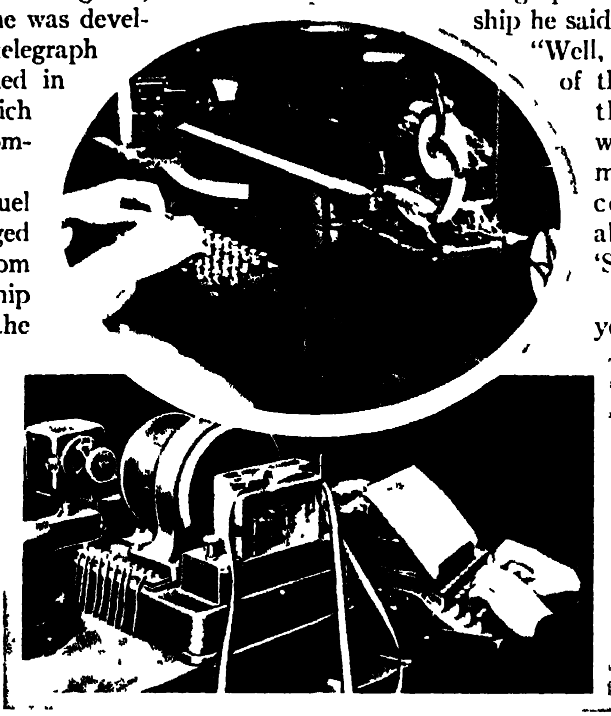
Yet in 1815 it took two days for the news of the great Battle of Waterloo to get from Belgium to England, just across the Channel. In the War of 1812 a great battle was fought at New Orleans a good while after peace had been made—because neither General Jackson nor the British commander knew that they were not supposed to be enemies any more. And long after that, if someone you knew had been ill in California you would not have known how he was getting on for many a long day.

Small wonder, then, that Samuel F. B. Morse, chief inventor of the telegraph, said it would "mark an era in human civilization"!

Ever since the early days of experimenting with electricity, in the eighteenth century, inventors had been teased by the idea that it ought to be possible to send messages over wires. If we can send a current, why not try to make it say something? All sorts of odd and complicated systems were worked out. One man used twenty-four wires at once, one for each signal he wished to use; another spelled out his message by a series of electric shocks to the different fingers of the receiving operator. But after scientists discovered how to generate electricity from chemicals, and worked out the relation between electricity and magnets, in the early years of the nineteenth century, more practical systems were invented. Two German professors, Gauss (gous) and Weber, put up an experimental line between their laboratories at the University of Gottingen; and

another German, Steinheil (stīn'hīl) of Munich, even devised a recording telegraph in which a moving needle marked down its message in dots and dashes on a ribbon of paper—a system which sounds a good deal like that later developed by Morse himself. At the same time, in England, Charles Wheatstone was developing an electric telegraph which really worked in practice, and which was later given a commercial trial.

Meanwhile Samuel Morse, a middle-aged portrait painter from New York, took ship one day in 1832 on the packet "Sully," returning to his native land after a a second term of studying art abroad. During the voyage the talk one night at dinner turned to the subject of electricity. The wonder was still new in those days, and Morse listened eagerly with the rest. One of the passengers showed an electromagnet he had bought in Europe and described some of the experiments he had seen in Paris. Someone else asked how fast an electric current could pass through a wire. "It is practically instantaneous," was the reply.



Photos by Western Union Telegraph Co.

News of births and deaths, of fortunes gained or lost, and many other messages besides, are sent out by these relentless machines to warm or chill the hearts of people far away. In the oval is the machine which sends out the stock quotations which appear on ticker tapes over all the country. In the rectangle is the machine that sends a cablegram.

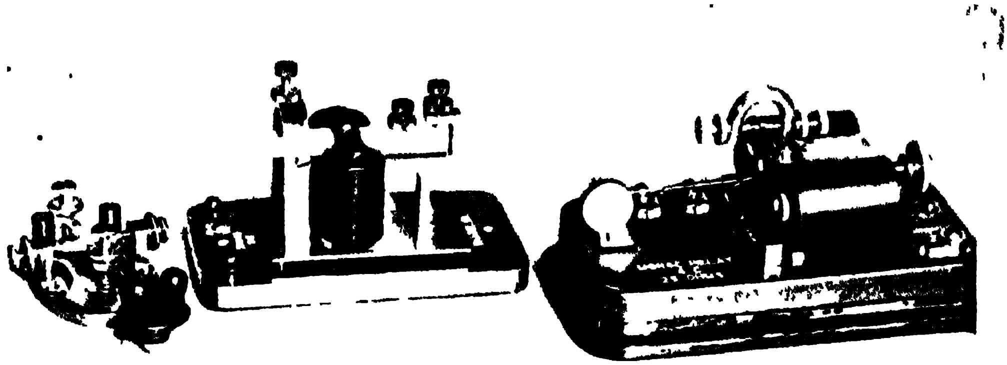
Morse thought of the electrical experiments of his college days at Yale. He had learned there that when the circuit is interrupted there is a flash of light. And all at once it now occurred to him that these interruptions might be used as a means of communication; perhaps an electric current might be made to carry messages almost with the swiftness of thought itself.

Now Morse knew nothing about all the other people who had had this same brilliant idea. He only knew that it haunted him. All the way back to America he turned it over and over in his head, wondering how he could make the current not only flash signals but record messages as well. By the time he landed he had made sketches of a telegraph. When he left the ship he said to the commander, "Well, Captain, if you hear of the telegraph one of these days as the world's wonder, remember that the discovery was made aboard the good ship 'Sully.' "

So the forty-one-year-old painter had found a new vocation—to invent a practical telegraph and persuade the public to take an interest in it. He had a good deal to learn to make up for his late start; and he had very little money. If he had not been lucky enough to find generous help, he could never have seen the thing through.

He worked in partnership with Professor Gale. Gale told him about Professor Joseph Henry, who had already made an electromagnet suitable for telegraph use and had sent signals over more than a mile of copper wire in the rooms of a school building. His discoveries, which he put at Morse's service, paved the way for the telegraph and other electrical inventions that followed.

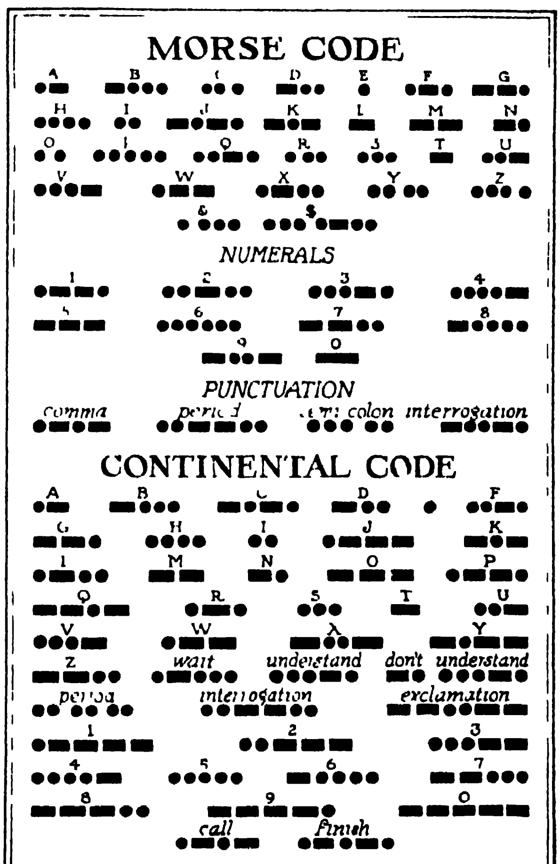
Then, in 1837, it was suddenly necessary to raise two thousand dollars for building a telegraph apparatus to show to the United States Congress, before it should decide to back the Englishman Wheatstone. Morse did not have the money. But in the nick of time young Alfred Vail came to his rescue.



These are the Morse instruments which once were used to send nearly all telegrams. To the left is the key, which sends the message. To the right is the relay, which is used to strengthen the current so that the message will be "clicked" out on the sounder, which is shown in the center.

Vail said he would build the apparatus for a one-fourth interest. Better, he made improvements of his own, so that some say the code system we call by the name of Morse is really Vail's.

The trial instruments were made in a secret room at the Vail ironworks. When all was ready Vail and Morse called in Vail's father. Vail sat at the sending board, Morse at the receiver. Vail's father wrote on a piece of paper, "A patient waiter is no loser," and handed the paper to his son. Click, click, click-click-click went the sending key, and on the instant the receiving end had the message all recorded on a piece of paper in the dots and dashes of the Morse code. It really worked!



The Morse code is still used to some extent in America, while a modification of it, the Continental code, is used in Europe. To make telegraphic messages go even faster, systems were invented to shorten messages by abbreviating words, so that what you have is a code within a code. A few letters strung together will stand for a whole sentence; and in this way long messages consisting of "dots and dashes" are sent and received in a very short time.

But it was another matter to get people in general and Congress in particular to see that it would work. Morse finally got a bill into Congress allowing thirty thousand dollars to build a telegraph line forty miles long. But while he was trying to get the bill passed, the long months dragged on and he grew poorer and poorer. Once he went to a pupil to ask for some money that was due him. The young man said he would be able to pay it next week.

"Next week!" said Morse, "I shall be dead next week—dead of starvation."

"Would ten dollars be any use to you?" asked the astonished lad.

"Ten dollars would save my life,"

Photo by Western Union Telegraph Co.

This is the way the simple Morse telegraph system works. When the operator at New York presses down the knob of the key, he causes two pieces of metal to touch each other, and so closes an electrical circuit. The electricity from the battery then flows along the wire from New York to San Francisco, coming back again through the earth to New York. At San Francisco the wire coils around—but does not touch—a piece of iron. When the electricity flows around this iron core, the iron becomes magnetic and will pull another piece of iron toward itself. A second piece of iron is attached to a brass bar so placed that when the magnetic iron core attracts the second piece of iron, the bar will hit against still another piece of metal and make a sharp "click." So when the New York operator presses down his key, the electricity flows around the metal core in San Francisco, turning it into a magnet which attracts the piece of iron attached to the brass bar. The end of the bar then hits the sounding metal. When the key is released the coil loses its magnetism and the brass bar flies back into place. By pressing and releasing the key, the New York operator can make a series of short or long "clicks." Since different combinations of these "dots and dashes" make up the letters of the alphabet, numbers, or punctuation marks, a complicated message may be sent clear across the continent- and indeed around the world—in this way.

answered Morse. He and his pupil went out and had a royal dinner together. It was Morse's first meal in twenty-four hours.

Morse kept on hammering at Congress, till he got the reputation of being a harmless though annoying crank. On the last day of the session, the bill passed the House - but it stuck fast in the Senate. Late in the evening, he gave up hope, and dragged himself wearily back to his room. After he had paid his board and lodging, he would have just thirty-seven cents left.

The very first person he saw next morning greeted him with congratulations! It was a Miss Ellsworth, daughter of a friend, come to bring the joyful news that the Senate had passed the bill after all, in the closing minutes of the session.

"If that line is ever completed," promised Morse, "you shall send the first message over it."

And that is how it happened that on May 24, 1844, Miss Ellsworth sat at the transmitter in the Supreme Court room in the Capitol at Washington and sent to Alfred Vail at the other end of the line, in Baltimore, the famous message, chosen from the Bible: "What hath God wrought!"

Morse himself lived long enough to see his telegraph develop into a network of communication over America and Europe and even reach into Asia. He lived to see the laying of the first Atlantic cable. Even more, perhaps, than at the wealth and honor that came to him, he must have rejoiced at the way his dream was coming true before his eyes—his dream that the telegraph would "mark an era in human civilization."

It was really his dream more than anyone's else; for the modern telegraph developed pretty much on the basis of Morse's work. But many astonishing improvements have been made in the telegraph since Morse's day. Morse's apparatus, for example, weighed about three hundred pounds, and that used to-day weighs about three.

Much more important is the number of messages we can now send over a wire. At first, of course, it was miracle enough to send one. But in 1872, just about the time of Morse's death, J. B. Stearns found a way to send one each way at the same time—the duplex system. The next year Thomas A. Edison—who had his finger in nearly every electrical pie—invented a way of sending two each way at the same time—the quad-

ruplex system. To-day, by the multiplex system, we can send as many as eight messages on a single wire at the same time. Operators type the messages on a keyboard much like the one on a typewriter. As a key is struck, holes are punched in a narrow, moving paper tape, with each letter or character represented by a special arrangement of holes. As the tape passes through the transmitter, electrical impulses are sent over the wire to the receiving machine, which translates them back into characters. The message is printed on moving tape and stuck on the yellow paper you receive at your door. Nearly all telegrams are now sent by automatic machine—either in this way or, if the circuit is short, by the telegraph typewriter shown below.

Of course these devices mean much cheaper and swifter service. By the old method one could hardly learn to send more than forty words a minute, but the machines can send ten times that many. Still greater speed is gained by what is known as the carrier system. By the use of a great many different tones and frequencies as many as 288 telegrams can be sent at the same time over a single pair of wires. Formerly there was often delay when a message had to be relayed at large centers. Now it can be hurried along by means of the reperforator switching system. A telegram is received in the form of perforated tape, which is switched at once to an outgoing line and sent on automatically to the city that is its destination.

More amazing still is the Telefax, which sends a message you have written out by hand and dropped into a slot. It automatically wraps your telegram around a revolving cylinder and sends it over the line to a receiving machine. When it leaves the machine it is an exact picture of the message you sent. This last invention makes the telegraph live up to its name, which is merely Greek for "far writer." From this invention it is only a step to sending pictures by telegraph—that is, by telephotography.

And even this is not the end, for the telegraph is invading the air waves. Many of the familiar poles and lines will be giving way to super-high-frequency radio relay systems, with broadcasting towers some thirty miles apart between the chief cities. The messages can be sent by radio with less danger of interruption from storms, electrical disturbances, and falling trees. It will allow over a thousand operators to send telegrams all at the same time over a single beam in one direction, and the equipment will cost a good deal less.

There are more than 2,000,000 miles of telegraph wires in the United States, and well over 200,000,000 messages go over them in a year. Besides that, there are all sorts of little telegraphic systems which we hardly think of as telegraphy at all. The ticker tape on which is printed the latest prices on the stock exchange rolls out its fateful length in business offices from New York to San Francisco. Many thousands of clocks in the United States are regulated by telegraph from the Naval Observatory. City fire-alarm systems and police alarms are really special kinds of telegraphs.

So the next time you see the telegraph boy with his yellow envelopes, try to imagine what a different world this would be if there had never been such a job as his to do.

This clever device is commonly called a "teletype" machine. If you and a friend of yours each owned one, you could write messages to each other that would be received in no time at all even if you were miles apart. You could even write to your friend while he was out, for he would find the message waiting for him when he returned.

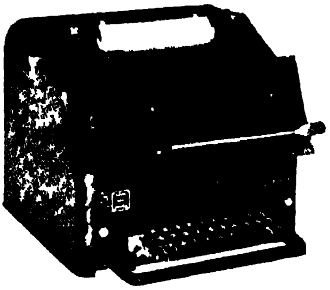


Photo by Bell Telephone Co

The motor of your instrument and the motor of your friend's instrument must be "synchronized"—that is, they must work together, at exactly the same speed. Suppose you tap out "a" on your machine; when your machine registers "a," an impulse runs along a wire to your friend's machine, which is also registering "a," and which then writes it down.

Reading Unit No. 10

WORDS UNDER THE WAVES

Note: For basic information not found on this page, consult the general Index, Vol. 15.

For statistical and current facts, consult the Richards Year Book Index.

Interesting Facts Explained

The first cablegrams, 10 101-2
Experiments in under-water telegraphy, 10 102
Telegraphic cables in Europe in the 1850's, 10—102
How the first cable was made, 10 103-4
How the "Niagara" and the "Agamemnon" laid the first cable, 10 104-6
How modern cables are made, 10 106
There are about 300,000 miles of cable now under water, 10 106
Why the first cable ceased to work, 10-106

Things to Think About

Why were under-water cables in use in Europe before the Atlantic cable was laid?
What advantage is there in having more than one cable between Europe and America?
How are cables damaged?
Why was the "Great Eastern" sent out to lay an Atlantic cable?

Picture Hunt

Name three men whose names will always live in the history of modern communication, 10 102

Related Material

How can pictures be sent by cable? 10 94, 99
Why are groups of five letters used in secret telegrams? 14—145
How can long messages be sent and received by telegraph in almost no time at all? 10 97
What difficulty had to be overcome before coast-to-coast telephone calls could be made? 10 112, 113
How does the telephone work? 1 518-20
How are your words carried to Spain when you speak from Havana to your friend in Madrid? 10 113
Why are submarine cables wrapped in gutta-percha instead of in rubber? 9 309
What device besides the cable is now used for transoceanic communication? 10 115-21

Summary Statement

The messages of the world constantly flow through the cables that lie, like great armored snakes, at the bottom of the ocean—a lasting monument to human perseverance.

In this picture, painted by Daniel Huntington, all the leaders in the laying of the first Atlantic cable are gathered together, at the home of Cyrus Field on Gramercy Park, New York City. Standing back of the table are David Field, with a law book, Chandler White, leaning forward with an expense account; Samuel F. B. Morse, the great electrician and inventor, and Daniel Huntington, the artist himself. The three who are seated are Peter Cooper, president of the company, Marshall O. Roberts; and Moses Taylor. Of the two standing at the right of the table, the one behind is Wilson G. Hunt, and the other is Field himself. He is pointing out on a chart of Trinity Bay the spot at which it will be best to land the cable.

WORDS *under the* WAVES

The Story of the Laying of the Atlantic Submarine Cable Is One to Make the Human Race Proud, for It Is a Story of a Marvelous Dream That Came True through the Untiring Perseverance of the Dreamers

IN THE late summer of 1858, England and America were all agog with the biggest piece of news that had been heard in many a day. It flew along the new-fangled telegraph lines that in a decade had spread a network over Europe and the United States. It traveled in letters and newspapers out beyond the wires to the end of the railway in the Nebraska prairie. It rode in the mail bags of the Pony Express from St Joseph to Sacramento, and sped round the Horn with the flying clipper ships bound for California. And the great piece of news was the fact that people in the United States were sending messages to people in England over some two thousand miles of wire laid at the bottom of

the sea. Men of thirty were speaking with awe of the wonders that had come to pass even in their short lives—steam railroads where there had been only stage coaches; steamships beating even the fastest clippers across the Atlantic; the mysterious force of electricity trained to carry messages along telegraph wires over land. And now this, surely the crowning achievement of man's invention and perseverance!

There were great doings in New York and London. Honors were heaped on Cyrus W. Field, the American business man who had seized upon the idea of connecting the two continents with wires, and had kept at it through thick and thin until this day of triumph. In England there were banquets and orations in honor of Professor William Thomson, the genius who had been chief electrician of the enterprise, and of young Charles Bright, the twenty-six-year-old chief engineer. Bright was knighted for his accomplishment. Queen Victoria sent a gracious message of congratulation to President Buchanan, expressing the hope that the cable would bind still more closely the friendship between the two countries. President Buchanan's reply was in the Queen's hands only a few minutes after it left the White House.



Here are three men whose names will always live in the history of modern communication. At the left is Morse, father of the telegraph; in the center is Bell, opening the first telephone between New York and Chicago; and at the right is Field, who, in the face of overwhelming odds, forwarded the project for a cable across the Atlantic.

Photos by Metropolitan Museum, Bell Telephone Co. and Western Union Telegraph Co.

The Very First Cables

No wonder there was marveling and rejoicing. Many a weary hour's work, many thousands of dollars, and many blasted hopes had gone before. Men had been working on the idea of under-water telegraphy for a long time even before Morse in America and Wheatstone in England had arrived at their successful land telegraph instruments. As far back as the year 1803, a man named Aldini (äl-dē′nē) had sent messages along a wire laid under the River Marne in France. Several years later, two German scientists communicated with each other over a wire laid under the river Iser.

In the days when it seemed to Morse that the United States Congress never would make up its mind to vote the money for his telegraph, he had gone out one moonlight night and had laid two miles of cable under New York harbor. Next morning he had even sent a few words over it; but then it had suddenly stopped working—a ship had come along, cut the wire with its anchor, and proceeded on its way. The year after Morse built his telegraph line between Washington and Baltimore, Ezra Cornell laid a cable underneath the Hudson from Fort Lee, New Jersey, to New York; it worked well until the winter's ice broke it. By the middle of the 1850's telegraphic cables connected Great Britain with Holland and Germany, and there were cables in operation between Denmark and Sweden; between Italy, Corsica, and Sardinia; and between Sardinia and North Africa. But little was known of the depth of the Atlantic, and the very thought of the tremendous length of cable that would be needed to cross the Atlantic staggered the imagination.

Then sounding ships established the fact that there is in the ocean between Ireland and Newfoundland "a gently undulating plain," at an average depth of two and a half miles. Matthew F. Maury, an American naval lieutenant and a great student of ocean beds, winds, and currents, said that this plain was "apparently placed there for the express purpose of holding the wires of a submarine telegraph and keeping them out of harm's way." But Maury added a warning: "I do

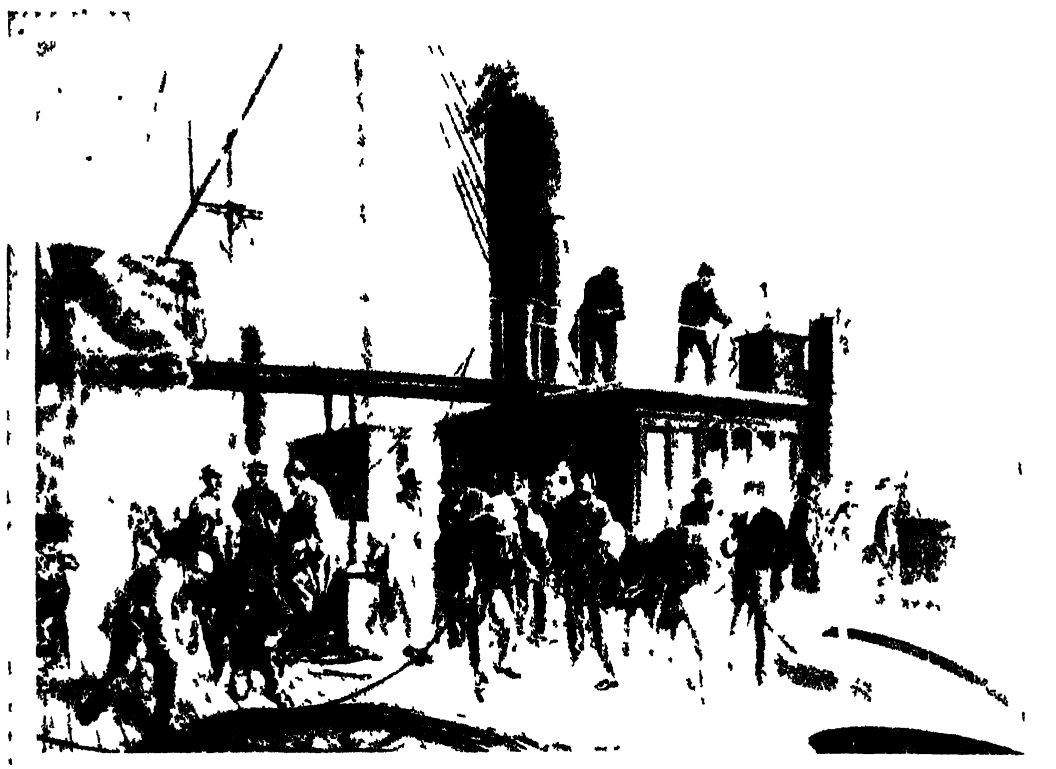


Photo by Rischgitz

When the "Great Eastern" steamed out on her second attempt to lay a cable under the Atlantic, she carried along enough cable to lay a complete line and to finish the one which had broken on her first trip, besides. But she did not have all the ingenious implements we have now to help us find the ends of broken cables. So though on this second trip she succeeded in laying one complete cable from coast to coast, it was not until after many trials that she finally picked up that broken end. She did it at last, however, and in our picture she has hauled a coil of it on deck in triumph, to splice another piece to it and extend it the rest of the way across the ocean as a partner for cable number one. For the more cables we have, the less likely are they all to go dead at one time. There are now twenty-one between Europe and America.

not, however, pretend to consider the question as to the possibility of finding a time calm enough, the sea smooth enough, a wire long enough, or a ship big enough to lay a coil of wire sixteen hundred miles in length." There were plenty of scientists to say quite flatly that all these things were impossible, and to let the whole scheme for a transatlantic cable go at that.

Cyrus W. Field

But luckily there was Cyrus W Field He was not a scientist, an electrician, or an inventor; he was a successful business man. But he had money, imagination, and persistence. He believed the thing could be done, and he had sense enough to get experts to help him. He consulted Morse, who told him he was sure it could be done Then he went to England, where he entered into an agreement with John W Brett and Charles Bright, who had already been successful in laying shorter submarine cables He engaged the services of other men who had distinguished themselves in electrical work, and he was able to find people who would put money into his project, wild though it seemed to most men.

By February, 1857, the first cable was being made It was to be laid from Valencia, Ireland, to Trinity Bay, Newfoundland, 1,640 nautical miles away or 1888.56 land, or statute miles An amazing quantity of materials is necessary to build a trans-Atlantic cable It takes 60,440 statute miles of iron and steel wire Then 678 tons of copper and 516 tons of gutta percha are required Add to these items 19,056 miles of permalloy tapes, 3,444 of cotton tapes, and 64,000 of brass tapes. And then finish off the list

Photo by Science Museum London

Here is the famous steamship "Great Eastern," which has the honor of having laid the first Atlantic cable that proved permanent. It is for this feat that she is now best remembered. But in her day she was famous even before that, for she was the biggest steamer which up to that time had ever been built

for good measure Special ships and special machinery had to be provided so that the cable could be paid out as the ship sailed The British government lent one of its warships, the "Agamemnon," and the United States lent the "Niagara," the finest frigate in the navy These, with some small attendant ships, made up what came to be called the Wire Squadron

The First Tragedy of the Atlantic Cable

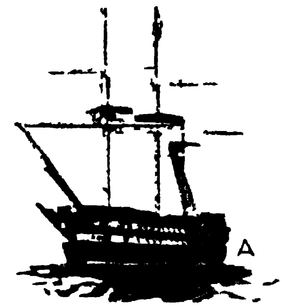
After suitable ceremonies and celebrations, the squadron sailed on August 5, 1857 One great coil of cable was in the hold of the "Niagara" Halfway across, when that coil was all paid out, the end of it was to be spliced to the beginning of the coil that the "Agamemnon" carried The British ship would then proceed to Newfoundland, paying out cable as she sailed For five days the anxious men on board the "Niagara" listened joyfully to the music of the paying-machine grinding out the cable. Then, after 380 miles of it had been laid, the cable snapped All that work and all that money wasted! There was nothing to do but turn back and wait for winter to pass before making another effort.

More money had to be collected from a public that had grown cold to the whole project Somehow it was done, and early the next summer the Wire Squadron sailed away again, this time without any celebrations at all The cable was to be spliced in mid-Atlantic, before any of it was laid, and then the "Niagara" was to sail for Newfoundland and the "Agamemnon" for Valencia Communications could be kept up between the two ships as long as the cable was unbroken On the way out the "Agamemnon," weighted with 250 tons of cable in her fore part, ran into a terrific storm that lasted a week, injured a number of the crew, and all but sank the ship But she came through to the meeting place, the cable was spliced, and the ships started off in opposite directions Messages passed back and forth between them until they were 109 miles apart Then the messages stopped The cable had broken again!

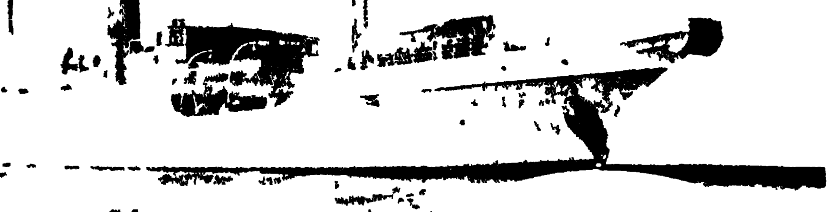
Danger of Whales and Icebergs

Both ships sailed for Queenstown, with things looking desperate indeed But Field and his associates actually persuaded the directors of their company to make still another attempt Five days after it had come into Queenstown, the Wire Squadron was

On this page are scenes in the laying or mending of cables. The "Agamemnon" (A) was the British warship which worked with the American "Niagara" in laying the first Atlantic cable. The picture at E shows a cable being landed in Spain

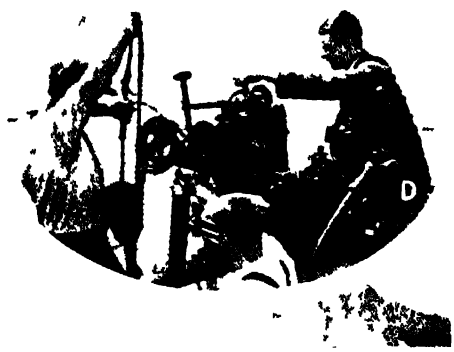


A



B

C



D

Great heroism and skill are sometimes needed to repair a cable that breaks. In 1932, for instance, an underseas earthquake broke ten of the twenty one cables connecting Europe and America. Cable ships such as the "Lord Kelvin" (B) and the "Cyrus Field" (C) hastened to the scene, in spite of the stormy weather. The electrical deep sea sounder (D) helps the experts on such ships to find the broken ends. When an end is fished up with the deep sea cutting grapnel (F), it is attached to a buoy (C) and left to float until the other end is found and spliced to it

E

F

Photos by Western Union Telegraph Co

bound for the mid-Atlantic once more. The cable was spliced, and the ships began their journey again, with their paying-out machines grinding away like coffee mills. Once a huge whale sent everyone's heart into his mouth by grazing the precious cable, but he did not break it. Another time there was grave danger from an iceberg. Once an American frigate headed across the stern of the "Agamemnon" from which the cable was reeling off into the sea. It was driven off by the energetic barks from the guns of the attending "Valorous." The cable held.

Messages across the Atlantic

On August 5, 1858, exactly a year after the first venture, the "Agamemnon" landed her cable at Valencia. A little later a message came through the wire saying that the "Niagara" had brought hers ashore on Newfoundland. And so there was reason for banquets and rejoicings on both sides of the Atlantic that summer.

But the rejoicings were short-lived. About two months later, after some seven hundred messages had been sent back and forth beneath the waves and men had begun to believe that the wonder was actually true, the cable ceased to work.

Now Professor Thomson—the great scientist who later became Lord Kelvin—and other experts had given warning that the cable was not stout enough. Water is itself an excellent conductor of electricity, and an electrical current passing over a wire in water sets up in the water itself currents going in the opposite direction. This slows up and weakens the current in the wire. Not enough allowance had been made for this pull of the waters. The cable had not broken; it had simply gone dead. Still, the worst was really over: the cause of the trouble was known. And it had been proved that a cable more than two thousand miles long could be laid on that plateau in the ocean bed between Ireland and Newfoundland.

Field and his associates started all over again to raise money and make a better cable. Now they had against them not only the public unbelief but the confusion and strain of the Civil War as well. Yet they hung on, and by 1865 a new company had been formed and the "Great Eastern," just then the heroine of the seas because she was the biggest steamship that had ever been built, started out with a stronger cable. It was 2,300 miles long and weighed 4,000 tons.

Even this cable broke. But another was sent out on the same ship. And on July 27, 1866, real and lasting success crowned all the years of heartbreaking effort. Since then cable messages have flown back and forth beneath the waves every day.

We are so used to marvels in our day, when business men of New York and London call each other up by wireless telephone casually of a morning, that it is hard for us to realize what an achievement it was to lay that first Atlantic cable. We may even forget the marvels that the submarine telegraph itself does every day. Yet there are now not one but twenty-one cables under the Atlantic between North America and Europe alone, and in the whole world there are something like 300,000 miles of cable under water. As with the land telegraph, more than one message may now be sent over the wires at once, and speed and cheapness have made cabling much more practical and popular. Its present cost is amazingly small.

How a Cable Is Made

All through a cable, from shore to shore runs a core of copper wires—the telegraph line itself. These are inclosed in a sheet of gutta percha or synthetic materials. Then there is a cushion of jute yarn, around which an armor of steel wires is wound spirally. Outside the steel-wire armor are two windings of jute which are tarred. Except for the part of the cable to be laid in very deep water, there is brass tape around the gutta percha near the core; this is to protect the telegraph from little creatures of the sea, such as the teredo worm, who like to bore holes in such things as cables.

So the cable lies, like a great armored snake, along the hills and valleys of the ocean. Dreamlike undersea gardens bloom about it, and outlandish fishes brush it with their fins. And through it constantly flow the messages of the world.

Reading Unit No. 11

HOW THE WIRES CARRY WORDS

Note: For basic information not found on this page, consult the general Index, Vol. 15.

For statistical and current facts, consult the Richards Year Book Index.

Interesting Facts Explained

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The principle on which the telephone works, 10-110
How Reis and Bell experimented with the telephone, 10-110
How Bell proved to distinguished men that the telephone would work, 10-112
The first telephone exchange set up in New Haven, 10-112
The first coast-to-coast telephone calls made in 1915, 10-113
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How are voice sounds strengthened when they grow faint from traveling over long distances?
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What has been done with telephone wires in our cities?

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Summary Statement

Although at first the telephone did not interest the public much, it was a wonderful invention. When ways were found to strengthen the sound of the voice, long-distance calls became possible. Now our voices can be heard over the telephone in distant lands, and the business of the world is greatly speeded.

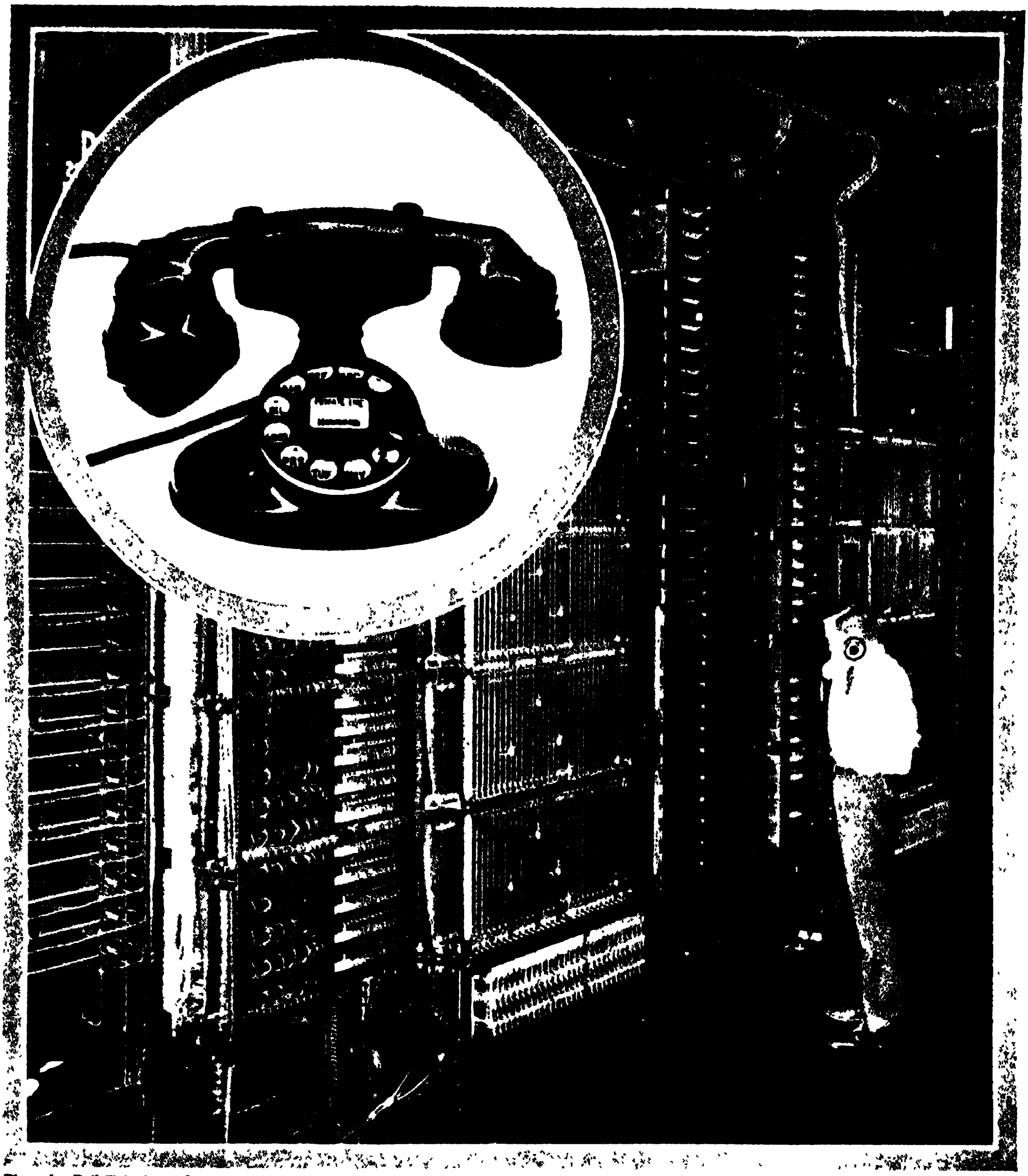


Photo by Bell Telephone Company

This is a dial telephone "switchboard" in the central office. But where, you may ask, are the girls with head phones who once sat in every central office? They are there, but since the invention of the dial system we no longer rely on them to get our numbers. The mechanism will do that quickly and accurately. The most important part of this new equipment consists of electromagnets, which can pick out your particular telephone line from the ten thousand which a switchboard like this controls. When you lift the receiver of your dial phone a current flows into your line and a mechanism at the switchboard starts sliding over the terminals of a group of lines until it feels yours. Instead of the "voice with the smile" you hear a buzz, and when you dial a number, at every click a pulse of current passes through some electromagnet in the mechanism in the central office. That mechanism puts through the call. The telephone pictured above, which is in common use to-day, is called a "cradle phone," or hand set, and combines transmitter and receiver in one piece.

Of course operators are still necessary, for no machine yet invented is entirely independent of man. As a matter of fact there are more operators now than ever before. "Information" is still an operator, not an electromagnet, and operators still put through long distance calls. Teletype, picture transmission, radio telephony, all those marvels of modern life pass through switchboards like this one. The automatic switching system is a fairly recent improvement. A United States patent for one was issued as early as 1879, but it was not until 1889 that A. B. Strowger invented the system which, a good deal improved, is now in use. And it was not till 1921 that the first complete automatic exchange was put in operation. To-day a large proportion of the switchboards in this country are automatic. Especially, they have been installed in a good many large cities.

Photo by American Tel & Tel Co

HOW *the* WIRES CARRY WORDS

Tens of Millions of Telephones in This Land Will Let You Talk to a Cousin around the Corner or a Friend across the Sea

"MR. WATSON, come here. I want you."

The speaker was in the attic workshop of his boarding house and Mr. Watson was in a room down the hall. Seconds later he was in the workshop, out of breath with excitement.

"Mr. Bell!" he shouted. "I heard every word you said—distinctly!"

This was the first message ever sent over a telephone.

The year was 1876, the place was Boston, and the inventor, standing there pale and dark and excited, was a young Scotchman named Alexander Graham Bell. He and Thomas Watson, his assistant, had been working patiently for many months before that momentous day in March when Bell's voice from the attic sent Watson plunging breathlessly for the stairs.

Young Bell had been interested in studying the human voice ever since he could remember. He was born in Edinburgh, in 1847, the son of Alexander Melville Bell, who was well known for his system of teaching deaf and dumb people to talk and to understand the speech of others. Graham and his brothers learned a great deal from their father, and liked to make experiments for themselves. At one time they made a speaking machine. One brother made lungs out of a bellows and vocal cords out of rubber. Graham got hold of a skull, moulded a tongue for it out of rubber stuffed with cotton, and made the soft parts of the throat with the same materials. Then he arranged joints so that the jaw and tongue could move. At last they put the whole thing together, and sent air through the bellows. "Mama! Mama!" the thing squawked to the vast delight of the proud young inventors. They put the creature on the stairs of the apartment, hid behind a door, and made it cry out. What was their joy to see a lady come out of another apartment, look all around in bewilderment, and say, "Mercy, who has left a baby on the stairs?" She never found out.

When Graham grew older, he became his father's assistant, and was well known himself for his work for the deaf. He worked hard at improving his father's system of "visible speech." The first article he wrote

was about what happens in the mouth when we make vowel sounds. This article his father sent to a friend, and through the friend Bell heard about the work of the German scientist, Helmholtz. Helmholtz had made tuning forks sound by means of an electromagnet, and had even tried, by combining tuning forks of different tones, to reproduce the sounds of the human voice. After that, although Bell never gave up his work for the deaf, he became more and more interested in this notion of reproducing the voice by electricity.

Bell knew, too, of what another German scientist named Reis (rīs) had done. Reis had had the idea of making sound strike against a disk or metal plate and set up vibrations that would make and break an electric current. Then he wanted to use this current to set up in another piece of metal vibrations exactly like those that had made the current in the first place. If he could do this he would, of course, reproduce exactly the original sound.

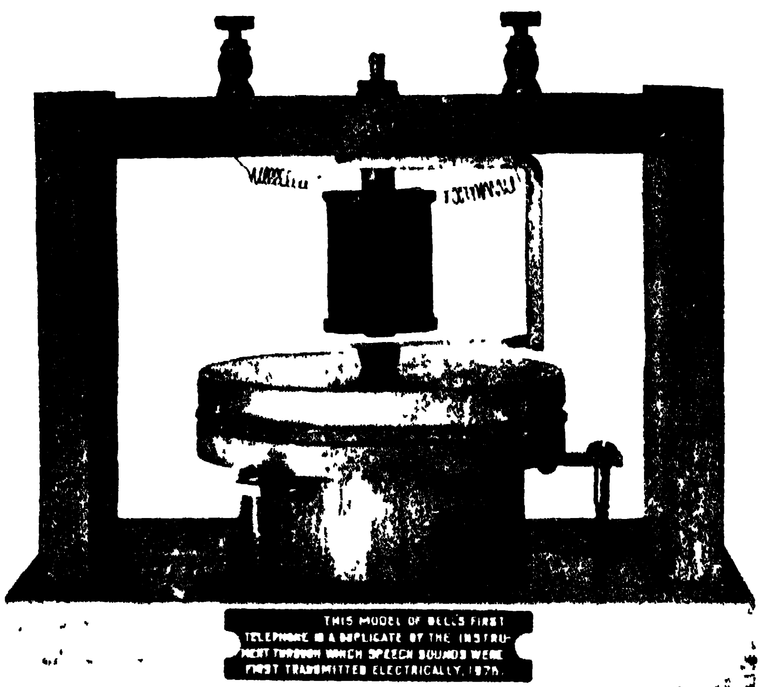


Photo by Bell Telephone Laboratories

This is a model of Alexander Graham Bell's first telephone instrument the one through which speech sounds were first transmitted electrically, in 1875. This device works on exactly the same principle as our telephones do to-day—but how different it looks!

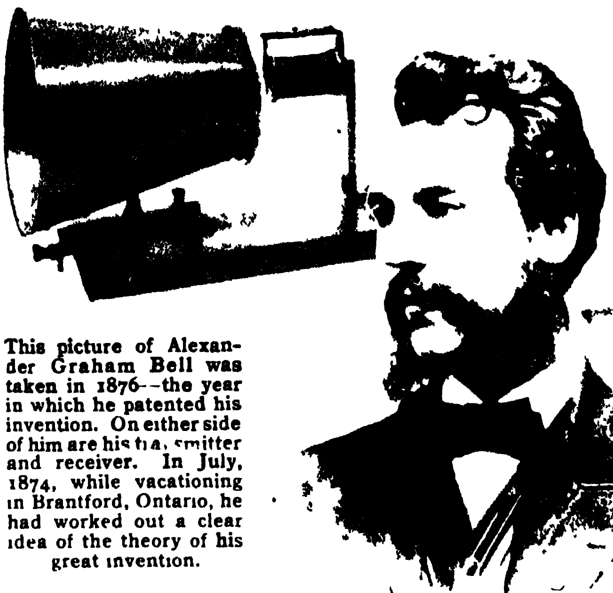
How the Telephone Works

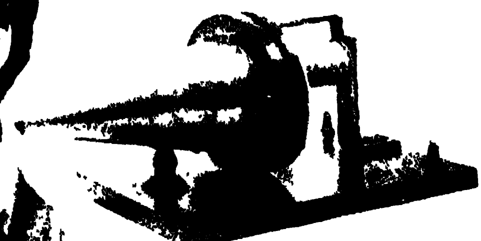
Now this is almost the principle on which the telephone works. When you telephone to-day, your voice sends sound vibrations against a thin metal disk in the transmitter, or mouthpiece. These vibrations produce changes in an electric current, which is carried along a wire until it influences a magnet in the receiver held to the ear of the person to whom you are speaking. When the magnet vibrates the disk in the receiver, sound vibrations are produced which are just like the words spoken. So you say, "Hello, Jack! how's everything?" and like a flash the words turn into electric current, dash over miles of wire, and turn into words again—"Hello, Jack! how's everything?" And almost before you have stopped speaking, Jack answers, "Oh, fine. When are you coming over?"

But Reis never got so far as sending words. He hollowed out the bung of a barrel and covered the hollow over with a bit of sausage skin. This made a diaphragm that would vibrate to sounds that struck against it. To this he fixed a strip of platinum wire, and as the metal rose and fell with the vibrations of the diaphragm, it made and broke an electric current. This was the sending instrument. The receiver was a knitting needle with a coil of wire about it to make an electromagnet; it was placed on a violin as a sounding board. So far, so good. He had made a sort of telephone, for the word comes from two Greek terms meaning "far sound" or "sound at a distance." But the sounds in Reis's telephone were not separate words, and so did not do anyone much good.

And now young Bell would work the idea out and make it more practicable. In 1870 the Bells moved to Canada, and in a year or

two Graham was in Boston as an instructor in a school founded to teach the deaf by the Bell method. He had a private class to teach other teachers, too, and lectured at Boston University. He lived for three years with a relative of Thomas Sanders, a wealthy Haverhill merchant, and taught Sanders' small son, who had been born deaf and dumb, to speak and understand "visible speech." He also helped teach Mabel Hubbard, who had lost her hearing and speech when she was a little girl. These two pupils were very important in Bell's life and in the history of the telephone because their grateful fathers financed his experiments; besides, he married Mabel Hubbard.





This picture of Alexander Graham Bell was taken in 1876—the year in which he patented his invention. On either side of him are his transmitter and receiver. In July, 1874, while vacationing in Brantford, Ontario, he had worked out a clear idea of the theory of his great invention.

Photos by Bell Telephone Laboratories and the National Museum

Guarding the Great Secret

As Bell's great idea grew in his mind, he gave up all his pupils but these two, and worked hard, along with Watson, in his Boston workshop. He was afraid someone would steal his experiments. So he worked in secret, and bought his supplies in different shops—a bit of wire here, a piece of metal there—so that nobody might suspect what he was doing. He knew much more about sound than he did about electricity. But when he had talked with the aged inventor, Joseph Henry, about his experiments, and had confessed that he lacked electrical knowledge, Henry had said simply, "Get it!" That was encouragement enough for Bell, and he went to work with a will. Besides, Watson knew a good deal about electricity.

The Hard Road to Fame

So they worked harder and harder, and Bell got poorer and poorer. Mr. Sanders and Mr. Hubbard were getting a little tired of helping the young dreamer who did not seem to be getting results. And Mabel's father did not want her to marry a penniless would-be inventor. But already an instrument had been made to carry the sound of a plucked reed along a wire into another room. Bell was sure it was only a matter of time before he would succeed. Then came the great day in March, 1876, when Bell summoned Watson by telephone.

Not that their troubles were anywhere nearly over, even then! Mr. Hubbard wanted Bell to exhibit his new invention at the Centennial Exposition being held that year in Philadelphia. In spite of all his efforts, and even though he was one of the commissioners of the exposition, the best location Mr. Hubbard could get for Bell was in a corner under the stairs. When it came time for him to go to Philadelphia, Bell did not have enough money to buy his train ticket. Mabel Hubbard's tears of bitter disappointment made him the more determined to go. In the end, ticket or no ticket, he jumped on the train and went.

So one Sunday afternoon he found himself standing near his corner under the stairs, hoping that the judges who were rating the

exhibits that afternoon would not pass by his "improvement on the telegraph." His heart sank when they paused only a minute before the odd-looking instrument and then seemed about to move on. After all, besides being tucked away in a corner, his precious invention had only eighteen words in the catalogue; and as for improvements in the telegraph, did not the Western Union have a breath-taking exhibit of telegraph instruments which could actually print?

Just then, like a prince out of a fairy tale, there came on the scene a distinguished foreign visitor, Dom Pedro II, emperor of Brazil.

Photos by American Tel & Tel Co and Bell Telephone Laboratories

At the top is a view of Broadway and John Street in New York City as it looked in 1890; and at the right is a view of the same spot as it looks to-day. What has happened to the poles and wires? They have been bundled into cables and put underground. At the left is a cross section of one of these cables. It contains 1,800 wires. Imagine how a street would look if these wires were strung on poles overhead!

"Why, Mr. Bell," he said, coming up with outstretched hands, "what are you doing here? What a pleasure to see you again!" And he explained to the others that he had met Bell in Boston, when he was thinking of setting up in Brazil a school for the deaf patterned after the one where Bell was teaching.

So Bell had the ears of all the judges as he explained his invention. Then he gave Dom Pedro a receiving instrument, and himself took up a sending instrument at the end of a wire strung around the big exhibition room. When the words came through, the Emperor nearly dropped the receiver, exclaiming "Good Heavens, it *talks!*" All the judges had to try it after that. Joseph Henry was there, and the Englishman, Sir William Thomson, just then perhaps the most noted electrical engineer in the world, on account of his part in the laying of the Atlantic cable. Thomson said, "It is the most wonderful thing I have seen in America."

So many other people had been working on similar ideas that Bell's patent on his device led to no less than six hundred lawsuits to decide who really invented the telephone. They were all decided in Bell's favor.

Yet for a time the public was not much interested in telephones. The London "Times" called Bell's invention "an American humbug," and a staid technical paper was sure that "nobody would care to trust important messages, sometimes involving life and death, or thousands of dollars, to being sent in such a manner." The Western Union Telegraph Company refused to buy Bell's patents, considering his price of $100,000 too high.

But the same men who had financed Bell's experiments now formed the Bell Telephone Company, which was soon to grow into a vast system. At first the telephones had to be rented in pairs, and you could talk only with the person who owned the other half of your pair. In 1878 the first telephone exchange was set up, in New Haven, with twenty-one subscribers. By that time messages could not only pass among any of the twenty subscribers to the exchange, but long distance telephoning had begun. The night Bell and Watson managed to make themselves understood over a telephone between Boston and Cambridge—a distance of two miles—they danced so wildly in their stuffy

little room that the landlady threatened to turn them out.

By 1880 there were more than thirty thousand telephones in the United States, and the number kept growing. When the patent ran out, competing companies sprang up, and for a while it was necessary in some towns to have two or three telephones if you wanted to be able to call up all your friends. Of course people protested lustily against this foolish and expensive arrangement, and so most of the smaller companies either sold out to the Bell System or made arrangements to connect their subscribers with it. Today the Bell system and the connecting companies serve practically all the telephones in the United States.

Talking from Coast to Coast

It was not till 1915 that one could telephone from coast to coast. Alexander Graham Bell was an imposing old man then, known and honored all over the world. He sat at a telephone in New York City and called up his old friend Watson in San Francisco.

"Mr. Watson," he said, "come here. I want you." And almost on the instant, back across 3,400 miles, came the answer: "I got it. I got every word!" And then Watson added with a chuckle, "But this time it would take me a week to come!"

The Telephone Is Improved

By 1915, of course, all sorts of improvements had been made, the inventions of a number of men, Thomas Edison, David Edward Hughes, Lee de Forest, John Ambrose Fleming, and others. That coast-to-coast call could never have been made if ways had not been found to revive and strengthen the voice sounds when they had grown faint from traveling over long distances. It had also been discovered that a saltspoonful of carbon granules in the transmitter, rubbing against each other when they were agitated by the voice vibrations, could greatly vary the electric current. Wires were being taken down from overhead poles and sheathed in cables of lead that could be laid underground; in every big city the population already walked over streets underlaid with these highways of speech. By 1915, too, the beginning of telephony by radio had been made; for in that year speech was transmitted by wireless from Arlington, Virginia, to San Francisco and Honolulu, and to Paris.

Bell died in 1922, and so did not live quite long enough to hear a telephone conversation across the sea. In January of the very next year after his death, telephone officials talked for two hours from their offices in New York to a group of scientists and engineers assembled in London for the test.

Telephoning across the Sea

And yet when you stop to think about it - of this marvelous thing which began a good deal less than a century ago- it is so startling as to make you catch your breath. Suppose you are in Havana, Cuba, and have to get in quick touch with somebody in Madrid, Spain. You speak into the telephone transmitter, and the words fly along a wire in a submarine cable to Key West, Florida. Then they follow land lines through Miami, West Palm Beach, Atlanta, Richmond, Washington, Philadelphia, and New York, and on to Lawrenceville, New Jersey. At Lawrenceville, they take the wings of radio to Madrid. And they go with such incredible swiftness that your friend in Madrid can answer them as if he were talking with you face to face!

At repeater stations between Havana and New York, the weakened voice waves are given new energy a hundredfold stronger. At Lawrenceville, the great radio transmitter serves as a giant repeater with enormous amplifying powers. But even then, when the voice waves arrive overseas, they are the faintest of whispers and have to be amplified again before they are sent to the Madrid telephone.

More than half the telephones in the world are in the United States; there are twenty-six for every hundred persons and over 40 million in all. There are about fifty for every hundred persons in San Francisco more in proportion to the population than in any other city in the world.

Reading Unit No. 12

THE ROMANCE OF RADIO

Note: For basic information not found on this page, consult the general Index, Vol. 15.

For statistical and current facts, consult the Richards Year Book Index.

Interesting Facts Explained

How scientists felt their way toward wireless telegraphy, 10-115
What Marconi's first transmitter was like, 10 116
How Marconi heard the first message through the air over the Atlantic, 10-116
Inventions that made it possible for the radio to do the work of a telephone, 10 118
The first radio broadcasting program, 10 119
The romance behind a broadcast, 10 121-A-21-G
How your radio works, 10 121-H-21-R

Picture Hunt

How do receiving stations catch the messages sent through the air from foreign lands? 10-115-18
How are radio programs transmitted and received? 10 119-20

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Why are transformers used in the transmission of electric energy? 1–510-11
Why do electric bulbs and radio tubes "burn out"? 1–525
What part did the radio play in making the screen talk? 10-503-6
How is radio used in television? 10 124
What does the microphone do? 10 118, 500
What great things has the radio done for the old phonograph? 10-449-500

Practical Applications

How do ships at sea use the radio? 10-115-16, 121
What difference has the radio made in our homes? 10–118-21

Leisure-time Activities

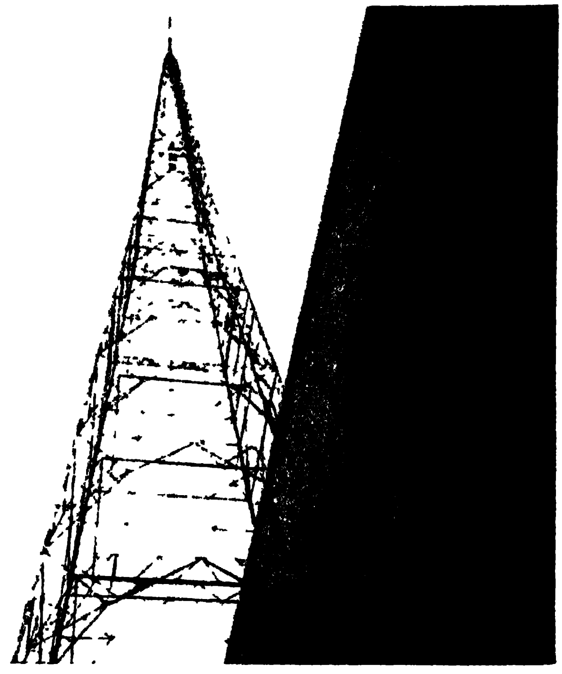
PROJECT NO. 1: Build a simple crystal radio set.

PROJECT NO. 2: Visit your local broadcasting station.

Summary Statement

The change from telegraph to telephone put the radio in all our homes. As soon as that change was made, we could get any sound from anywhere, and a new world was brought to our firesides.

This FM broadcasting tower is on Red Mountain in Alabama. Radio towers are now a common sight, but they were strange objects earlier in the century. Imagine the angle from which this neck-craning view must have been shot. The mountain top is more than 1,000 feet above sea level, and the tower on which the 108-foot antenna is fixed is 450 feet high. The very location of the tower helps to make a fine broadcasting station.



The ROMANCE *of the* RADIO

One of the Greatest Marvels of Science Is the Astonishing Invention That Brings the Voices of Speakers or Singers from Anywhere on Earth Right into Our Homes

THERE is a famous little poem which says that the first shot fired in the American Revolution was "heard round the world." That was only poetry, of course, when it was written; the man who wrote it never imagined that any shot would ever be heard more than a few miles away. But to-day anybody can hear a shot fired on the other side of the world if he wants to listen to it. You may yourself have sat at home somewhere in America and listened to Big Ben striking the hour in London; and many a person in Asia and Africa and Australia was listening to the same bell at the same moment.

Only a few years ago radio was all but unknown to most of us. It was a good sort of wireless telegraph for saving ships at sea, but nobody was dreaming that it would soon be bringing speeches and music from far away right into our homes. It was a fine thing to signal ships with, but as yet it had no voice.

How did it suddenly get a voice? What is radio, and where did it come from in the first place?

Among the scientists who first felt their way toward wireless telegraphy there are four pioneers most worth remembering. There was James Clerk Maxwell, who showed us how electricity moves in waves (1873). Then George Francis Fitzgerald told us how to produce electro-magnetic waves in space (1883). Heinrich Rudolf Hertz (hĕrts) found out what these waves are really like in length and frequency (1887). And Guglielmo Marconi (gōō-lyĕl'mō mär-kō'nē) took out the first patent for sending signals through space by means of electric waves (1896). On March 3, 1899, the first wireless report of an accident to a ship at sea brought prompt rescue from boats that put out from the shore.

That was the history of the early days of the wireless telegraph, a marvelous thing only a few years ago but now beginning to seem a little old-fashioned! Once we knew that electric waves could be sent out into space, it was only a matter of time before someone would find out how to capture the waves and make them register their beats. The beats would spell out a message.

Once Marconi had worked the puzzle, it was a simple matter to send the first messages, or radiograms. The transmitter was just an induction coil with the spark gaps connected with an aërial, or a wire in the air. An induction coil is an arrangement for making a very small current jump in a spark across a gap. When the circuit was closed and the gap was sparking brightly, a continuous series of waves was sent out into space from the aerial—in the same general way in which a series of waves is sent rolling from a stone you drop into the water. With the Morse code to go by, a short series of waves would mean a dot and a longer series a dash.

At the receiving end the waves reaching the aërial would start a current in it which would be detected by Marconi's wave detector. Through a head phone the buzz of dots and dashes could be heard, and so the message could be read.

The distance that Marconi's waves could travel depended on the strength with which they could be thrown out. A big splash in a pond throws out waves that travel farther than those from a smaller one. By 1899 there were stations that could send radiograms from France to England. Two years later there was no trouble in sending them two hundred miles. Soon after that Marconi was trying the great experiment of sending them across the Atlantic. It was a great day when the first man reached out through the air to send a message over the ocean.

Photo by Photopress London

Guglielmo Marconi, an Italian electrical engineer, was the clever inventor who first discovered how to send signals through space by means of electric waves. He was born at Bologna, Italy, on April 25, 1874. It was there that he made his first wireless experiments, and by 1896 he had made a really workable apparatus for electric-wave telegraphy. His device was so simple and compact that it was soon taken up for ship and shore signaling and for general communication at sea. But as yet it did not work for long distances. In 1896 he went to England and continued his experiments there; and in 1898 he set up permanent stations fourteen and a half miles apart. Later this distance was increased to thirty miles, and in 1899 he made wireless communication possible between England and France across the English Channel. In 1901 stations were set up at Cornwall and the Isle of Wight—200 miles apart. Finally, in 1902, he set up communication between England and Canada and the United States. He has been highly honored in Italy, and other countries have showered degrees and decorations upon him. He died July 20, 1937.

A station was set up to create the waves in Cornwall, on the west coast of England. It had a far greater power than any station had ever had before; but even so, some of the engineers were afraid the waves would not travel around the curved surface of the earth, while others thought they would always be too feeble to be detected across the ocean.

But Marconi was confident. When the station in England was ready, he went to Newfoundland. In a little time he had his receiver in order, and was ready to listen. He had told the people in England to send out the letter "S" at a certain time every day. On December 12, 1901, he first heard the three clicks that stand for the letter "S" in the Morse code. He had heard the first message through the air over the Atlantic.

The new thing was at once another wonder of the world. The warships of all nations were immediately supplied with wireless, and the Russo-Japanese War in 1904 showed the great value of it in naval strategy. Other ships at sea began getting the news of the world all over the ocean, and by 1904 the big liners were printing daily papers on board. In 1907 a transoceanic service for radiograms was in operation.

And yet this was all telegraphing. Even in 1918 there was no radio as we all know it to-day—no little machines in our houses that would bring us music from everywhere. All

Photo by Radio Corporation of America

Over direct radio circuits maintained by RCA Communications, Inc., these operators in the RCA Central Office, in downtown New York, are in constant communication with fourteen countries of Latin America.

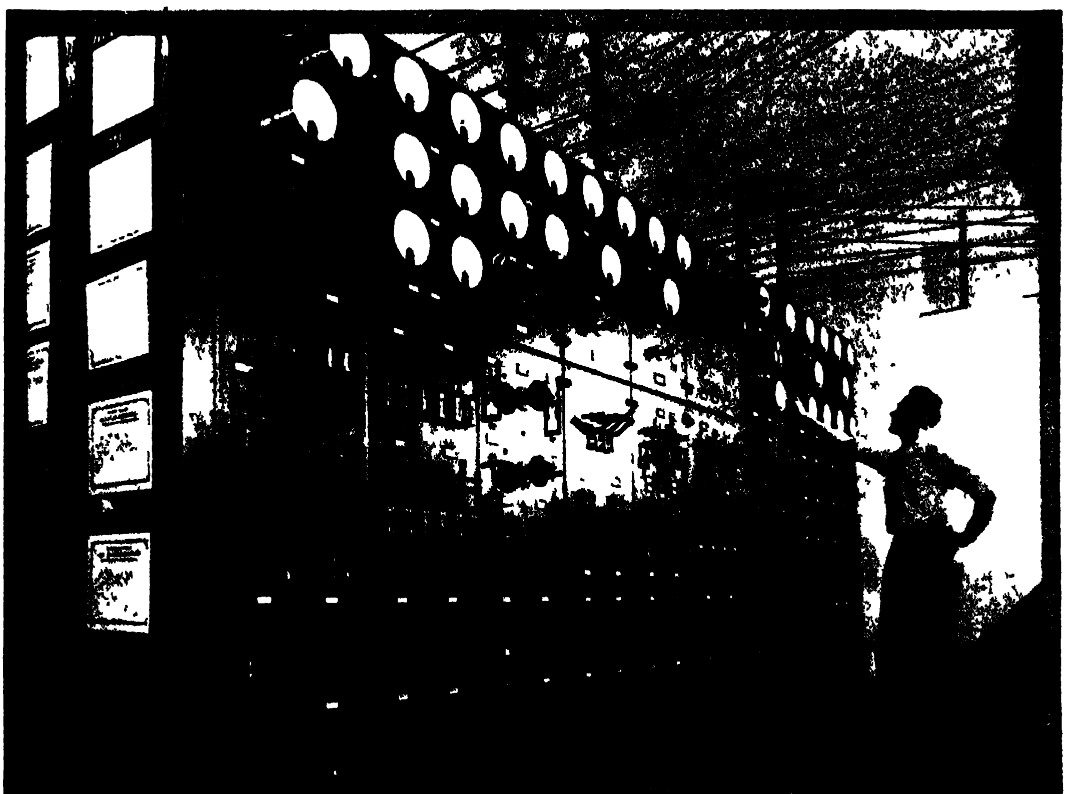


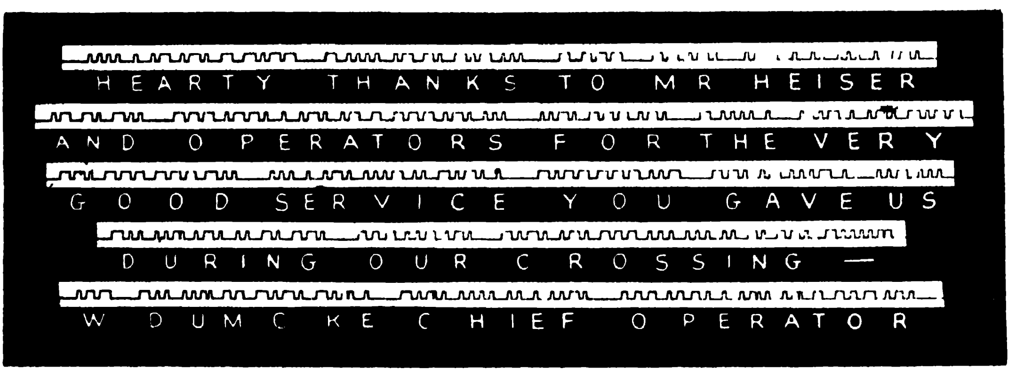
Photo by Radio Corporation of America

This impressive array of dials and levers is at the RCA Communications receiving station at Riverhead, Long Island. A technician is watching the current flow at the Power Control Board in the receiving room, where messages from across the sea are constantly pouring in. Overhead run the feeder wires which bring the incoming signals from the antennas outside to the receivers.

Photo by U S. Signal Corps

By means of the "walkie-talkie" radio he is carrying, the platoon leader in the center above will keep in touch with the tanks and his command post in the rear and can call for artillery support if necessary.

Below is the radio "script" sent by the gigantic German dirigible, the Graf Zeppelin, on a memorable trip it made to America before the Second World War. The message was picked up by a station of the Radiomarine Corporation of America, the incoming signals were greatly amplified and passed through a recorder, and finally those strengthened signals activated a sensitive pen which traced the wavy lines shown here. The translation of this record from the Morse dot-and-dash code is also given.



that came through the air as yet was a series of buzzes, clicks, and roars.

What put the radio in all our homes was the change from telegraph to telephone. As soon as we could make that change, we could get any sound from anywhere—voices, violins, pianos, orchestras, and entertainers of all sorts.

The first step in making the radio do the work of a telephone was made possible by two inventions—the vacuum tube and the microphone. The microphone was needed to put the sounds "on the air," and the vacuum tube to help in putting them on and to take them off. The microphone changes the strength of the wireless waves sent out. The vacuum tube magnifies the feeble wireless current received until it can reproduce the sounds in an earpiece or a loud speaker.

The vacuum tube was invented by John Ambrose Fleming, a noted British scientist, in 1904, and soon improved by Lee De Forest, an American. One of the first microphones had meanwhile been perfected; and by 1908 there was a wireless conversation between

Rome and Sicily, a distance of three hundred miles. In the next few years the distance was rapidly increased as the instruments were improved; and in 1915, with three hundred vacuum tubes, voices were heard between Arlington, Virginia, and the Eiffel Tower in Paris—a distance of 3,080 miles.

The Beginning of Modern Radio

Even then no one seemed to see any vast use for wireless telephony. But a vast expansion was coming, and it came almost overnight. By 1920 there were a great many amateur receiving stations here and there in America and Europe. Many of them had been set up by boys for the fun of picking messages out of the air. The boys were able to get telephone as well as telegraph messages that came floating by. What a sensation those in reach had when they first heard that a company in Chelmsford, England, was going to broadcast songs and music for an hour every evening for two weeks!

The first program went on the air February 23, 1920. It was heard distinctly 1,400 miles away, and with enthusiasm. In those days the air was almost wholly empty of flying radio waves. Very soon there were stations giving regular programs and a vast amount of broadcasting had begun.

Then everybody began getting receiving sets. Those who could afford it bought them complete and sat down to find out how far they could hear. Others started to make their own sets.

Bringing Order in Bedlam

As the broadcasting stations grew in number from day to day, their programs began to conflict with one another, until the listeners could often hear nothing but a general uproar. To stop the confusion the various stations were then assigned different wave lengths. A little pebble dropped into a pond may make tiny ripples hardly half an inch from one another, while a bigger stone may make them a foot or two apart. In the same fashion the Hertzian (hĕrt'sĭ-ăn) waves of wireless may be very long or very short. Engineers call them high and low-frequency waves. A radio set may be tuned to pick up any particular wave length and to ignore all the others. So when the different broadcasting stations use different wave lengths there is no interference among them.

To-day broadcasting is regulated by the Federal Communications Commission, and there are over 1,000 stations in the United States alone. Many of them are organized into great "networks." Stations in the same network use one another's programs and can all be tied together for a broadcast of unusual interest coming from one of the "key" stations in the network. That is what is called "chain broadcasting" or a "national hook up." The program will be put upon the air from many different stations at the same time, and carried to each station from the broadcasting studio by means of especially leased telephone wires. Besides the great networks there are also regional networks and independent stations. In fact the "walkie talkie" makes it possible for two persons to converse as they go about town on their business. For they can broadcast as well as receive on the set they are carrying.

We often hear it said that our country could never have come to be the great land that it is if there had been no newspapers. And that undoubtedly is true. If people had not been able to find out the facts and to have opinions presented from every angle, they never could safely have wielded the power the Constitution put into their hands.

But of late the newspapers have found a new ally one of the best friends good government ever had. Of course we mean the radio. It seems almost providential that this great invention should have come at just the time when the world has had to face the worst crisis in history and our own country has had problems more puzzling than any it ever had before. Americans have needed to know the facts, and they have needed to hear them discussed from every possible angle. Of course our journals are doing a magnificent service. But many people do not read the newspapers, or if they do, will refuse to read a paper that does not echo their own opinions. For such as these the radio is busy in their houses all day long, pouring forth information and opinions from every source. Some of it is sound and some is not, for the radio brings a certain amount of dishonest propaganda. But learn-

Young people now discuss modern problems over the radio as part of their training for citizenship.

ing to tell truth from falsehood is one of the first duties of a citizen. And keeping an open mind is perhaps the next. Surely it will be hard to stay narrow-minded if you listen constantly to the radio.

The Greatest Audience in the World

Of course it is for pleasure that most of us tune in. Radio has brought the world's finest drama, music, and vaudeville to the farthest corners of the globe. The truck driver bowling along over a lonely road at night realizes that while he listens to a singer or to his favorite comedian he will be in much less danger of falling asleep at his wheel. Young people on farms or in tiny distant villages may rely on a radio orchestra to play them music for their dances. Even explorers and lonely lighthouse keepers may listen to a speech by the president of the United States or the king of England. We know great men as we could never have known them in days gone by- we have heard the sound of their voices. But more than all this, homekeeping people—and even the bed-ridden can share in high adventure. They can hear the cold blasts sweep over Little America or listen to London's Big Ben ring in the New Year at midnight on December 31. They are citizens not of a township, but of the world.

For radio brings the whole wide world to our firesides. We hear the latest news a few minutes after the event has taken place. Often it is described even as it is happening. The big game is broadcast play by play, and at different times during the day the farmer can learn the current prices of farm products and the business man the latest stock quotations. Weather announcements warn the grower when to protect his crops from frost, and shopping guides tell the housewife what are the day's bargains. In a few moments a police network can be spread over the entire nation to catch a criminal, and every day certain city stations broadcast an alarm for missing persons. Some of those stations are owned and operated by the city in which they are situated, and in this way bring listeners close to the problems of their own municipality.

Radio Protects Life and Property

The rôle of the radio in saving human life is enormous. Warnings of storm and flood are sent into the areas in danger, or fire wardens are told of a threat to life or property. People in communities shut off from the rest of the world can call for help in time of stress. The radio compass guides the sailor, the radio beam keeps the aviator on his course. The insistent SOS calls for help when a ship is sinking. In fact, it is even possible to guide a ship or plane by radio alone, and bring it safe home when there is not a soul on board!

Radios are in our buses and trains and automobiles. The giant bomber may get its commands by radio, and the tank crew inside a walking fortress will maneuver according to

orders radioed from a plane that is directing the battle overhead. Under the name of radar (rā'där) direction finding has been so perfected that a device set, for example, far out at sea can tell a distant airplane or ship just where to find a moving submarine. Without the radio modern warfare could not exist. There are portable sets that a boy can slip into his pocket to take on a picnic, and others so tiny that a girl can fasten one to her umbrella handle when she goes shopping, relying on the umbrella's ribs to serve for aërial. Radios have come to be so inexpensive that many millions of families in the United States can own a set and keep abreast of the news.

A New Way to Go to School

There are some 160 million radios in the world. The United States alone has 84 million sets. It would be hard to say exactly how much all these radios help to educate people. We may not think of education as radio's chief purpose, but regular stations have educational programs, and schools and colleges have their own stations in many instances. And it is by no means only the so-called educational program that educates. Think of all the information and opinion that radio listeners hear! We acquire new ideas almost in spite of ourselves. Critics tell us that in music alone our taste and knowledge have improved immeasurably since the coming of the radio. The sale of recordings shows this, as does the interest in published programs of fine music.

Radio has also erased many of the differences that used to exist among us. Inhabitants of the most lonely districts can now share ideas that once were common only among people living in centers of culture. In many ways it is no longer easy to tell the country boy and girl from their city cousins. As a result people have a sense of "togetherness." And this is very important when there is a job to be done that needs unity of thought and action. We see how it works in time of war, of disasters of one kind and another, or in just normal elections or campaigns for community improvement. At such times it is necessary that people know quickly what is going on and radio provides the speediest communication. Moreover, the radio instrument itself is an educator. Many a boy lays the foundation for a career in science as he builds and operates his own set. The whole magic field of electricity may be opened to him by what, at first, seemed only a plaything.

The Radio Can Work for Peace

The radio can carry messages to help the people of the whole world to know and understand one another. Just as it can pull the people of a community or nation together to think and work on common problems, it can help rally the world's inhabitants. By spreading information, the radio can build respect and understanding among people of different customs and ways of living and so help do away with wars.

In 1941 the United States government began its "Voice of America" broadcasts to Latin American countries to help the people there understand its democratic way of life. Since World War II it has beamed programs to some twenty countries in as many languages. Many governments send similar short wave broadcasts to other countries to inform and build good will. The United Nations has daily broadcasts of its meetings in several languages.

We Must Not Be Radio Slaves

Of course the radio can misinform people and unify them for evil purposes as well as good ones. Controlled by totalitarian governments, it can be one of the best ways of deceiving people and stopping real thought. Government agencies such as the Federal Communications Commission in the United States and the broadcasting companies are responsible for seeing that radio is used for the benefit of all the people.

Every individual listener has a responsibility, too. He will listen with great care to differing programs, weigh facts and opinions, and try to do his own thinking. He will question what he hears. He will let the broadcaster and the government know that he wants an "airing" of all sides of a question that affects his welfare and the fate of the nation and the world, perhaps. People must be radio's master not its slave.

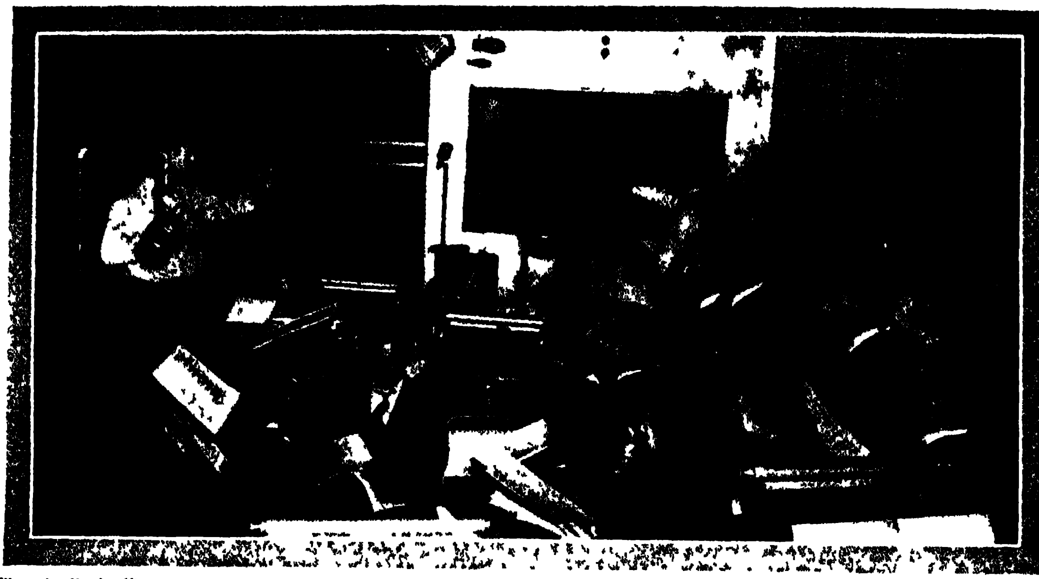


Photo by WGN Chicago

An operetta is in rehearsal at a big broadcasting station. Orchestra and voices have been trained separately and are now brought together for rehearsal under the program's musical director, who is standing at the left. Standing at the rear in the center is the producer of the program. He is wearing earphones that communicate with the control room seen through the window at the rear and is pointing to give the cue to the narrator of the operetta an actor who is standing just in front of the producer.

The ROMANCE BEHIND *a* BROADCAST

Here You May Learn a Little About the Instruments, the Labor, and the Planning That Go into a Radio Program

THE world is roughly divided between those who enjoy being entertained and those who do the entertaining. And the first are usually fascinated by the second, and the second are delighted at their chance to appear before the first. Consequently, when radio broadcasting came into being, the entertainers were rejoiced to know that their audiences could now be measured, not by hundreds, but by millions, and the audiences were enchanted at the prospect of the new marvel that promised them so much enjoyment.

This pleasure and excitement are perhaps the first thing one senses in a broadcasting studio. A miracle is worked there every moment of the day. A man sitting before a microphone in a small room can, if all the broadcasting stations of the world are linked together, be heard in every corner of the globe without speaking above a whisper. If it is an important event to be carried to the farthest island, every broadcast at that particular hour will be merely a repetition of this one man at his single microphone.

Of course there may be one, two, or a dozen microphones in any one studio, and several studios may be linked together to make up a single broadcast. You may hear Jane Smith in New York singing with Paul Jones's orchestra playing in Hollywood. These, however, are stunts. As a rule all the persons and instruments in any one broadcast are gathered together in a single studio.

Studios vary in size according to the program to be sent. It is naturally necessary to have a much larger room from which to broadcast a conductor directing a full symphony orchestra than would be needed to send the music from a banjo out over the air. And each combination of artists and performers needs its own special arrangement,

Courtesy Columbia Broadcasting System

All of us have listened with pleasure to programs sent out from this studio in one of the large broadcasting stations in New York City. The studio audience, whose laughter helps us to laugh when we hear it at home, is seated in the chairs in the foreground. In the rear at the left are the studio's acoustivanes (ȧ-kōō'stĭ-văn) wooden panels that, upon the pressure of a button in the control room, may be set at angles to each other to deaden the sound. When they are flat the sound is more brilliant but it will be full of echoes.

or placing, when it comes before a microphone. This is because the microphone is a kind of sensitive ear which is turned in only one direction and is deaf in every direction except the one in which it is pointed. Or it is like a very bright spotlight which makes visible whatever is in its beam but throws no light whatever on any instrument or performer not in its path of light. Thus if the "spotlight" or microphone "shines" too brightly on the big bass drum and is not "lighting up" the soft-voiced flute at all, it is clear that the flute will not be heard, because of the greater clearness of the powerful throbbing drum. To set the two sounds in proper relation to each other, the drum and the flute must be moved, so that the microphone's "beam" will fall very lightly on the drum and very brightly on the flute. Then both will be heard at once.

"Getting a Balance"

The placement of the instruments or performers in a broadcast in proper reference to a microphone is called "getting a balance." When all the units of a broadcast, whether singers, instruments, actors, or sound effects, are properly placed, a broadcast is "well-balanced," and the result is then most likely to give pleasure to those who have tuned in.

Controlling the Sounds

The studio itself in which all this occurs is a very highly specialized place. The first broadcasts were sent out from an ordinary room. But soon people realized that the broadcast was full of unpleasant echoes, that the sounds seemed to bounce around the bare walls and reach the microphone in successive waves, much as your own voice comes back to you when you shout between the solid walls of a canyon or inside the tiled walls of a swimming pool. So heavy draperies were hung on the walls to deaden the echoes—that is, to stop the sound from hitting the hard surface of the walls and bouncing back again, like rubber balls thrown at a barn door. That need for deadening the echoes was recognized as one of the most important things to remember in the building of studios.

An engineer will walk into a studio and clap his hands smartly together. If the slapping

sound repeats itself around him he knows the studio is too "live," and proceeds to do something about it. He may add movable draperies or put up porous fiber walls to absorb those extra unwanted sounds before they can reach the microphone and ruin the broadcast. Or he may direct that the walls be rebuilt in an arrangement like the folds of a half-opened fan. Then the sound will not be reflected in any one direction but will be sent back and forth in many directions and in that way split up and rendered comparatively harmless. Or he may build the walls with sliding panels. These can either be opened to reveal smooth surfaces behind them and so render the tone in the studio more brilliant—that is, fuller of almost inaudible echoes—or else the panels can have their muffling surfaces closed tightly together and in this way deaden the sound. Cork and composition materials under foot will do much to deaden the floors.

Sound-proofing a Studio

In large cities where there are street cars, railway trains, subways, and heavy trucks rumbling along in the vicinity, there is still another problem. For a microphone does not care what sounds it reproduces, and very often picks up this vibrant rumble from the very floor on which it stands, so that listeners hear what seems to be thunder at intervals a state of affairs which does not add to their delight. In mild cases the noise of traffic can be silenced by putting porous rubber pads under the microphones. But often this is not enough, and it is necessary to build studios which are "suspended"—which literally have an air space all around them and are cushioned at every point of contact with the building in which they are situated. A cross section of this type of construction, seen as if a huge saw had sliced across one corner, shows very clearly that several inches of empty air space completely surrounds the rooms where the broadcasting takes place. This will largely do away with the effects of outside vibration. The principle is somewhat the same as the one followed in relieving the jolting in an automobile. A passenger seldom feels the ordinary bumps in the road because of the tremendous improvement in springs and shock absorbers since the days of the hard-wheeled carriage, when every rut was felt and a day's journey left one very weary indeed.

Lighting and ventilation are of great importance in a studio. Usually the room is carefully air-conditioned, and lights are so placed that their rays reach every corner with a brilliance that guarantees the easy reading of musical notes or typewritten material.

Putting Up Bars against a Sound

The ideal studio would have neither doors nor windows, since these interrupt a scientifically designed wall and also make it possible for unwanted sounds to leak in. But of course there must be some means of getting in and out of the room. So you will find a double set of doors in every well-designed studio. This arrangement makes it possible for one set of doors to be shut tight before the second set is opened. This keeps out sounds from the outside and makes it possible to send a broadcast over the air without the addition of unexpected yells, the screams of fire sirens from the street below, or bursts of laughter from outside the studio walls. Many stories are told of such unexpected interruptions Most of them go back to the days before the double door was introduced.

But even triple doors will not prevent an uninvited stranger from walking in and shouting or making noises in blissful unconsciousness that the studio in question is "on the air." It is for this reason that you will find outside the broadcasting studios signs which usually warn in brilliantly lighted letters that the studio in question is either busy with "REHEARSAL" or else is actually "ON THE AIR." The second phrase, as you know, is the one used to give warning that whatever is going on within is being sent out to the radio sets of all those who are listening to the station at the moment. Of course the doors of a studio always open and close as silently as possible, and usually have small glass portholes in them so that an intruder will have no excuse for interrupting a broadcast.

Earlier we spoke of "balance" as highly important for a successful broadcast. Sometimes a good deal of experimenting is neces-

sary before everything is properly placed for going on the air, and naturally the officials cannot keep running across the street to tune in to see how their program sounds. In every studio, therefore, there is a mysterious little room which is one of the studio's most vital parts. It is called the control room, a name which explains itself. It is in this room that the broadcast is controlled. When you mix a fruit punch you pour all the ingredients into a big bowl and blend them until the punch has just enough of each ingredient. In much the same way we pour all the varying tones of an orchestra through several microphones into the "mixing bowl," which in this case is the control room. The mixing itself is done by the engineer, who has a knob for each microphone. By varying the turn of these knobs he can permit more or less of what is being poured into each microphone to enter the final mixture which is the broadcast that goes out over the air.

Photo by WGN, Chicago

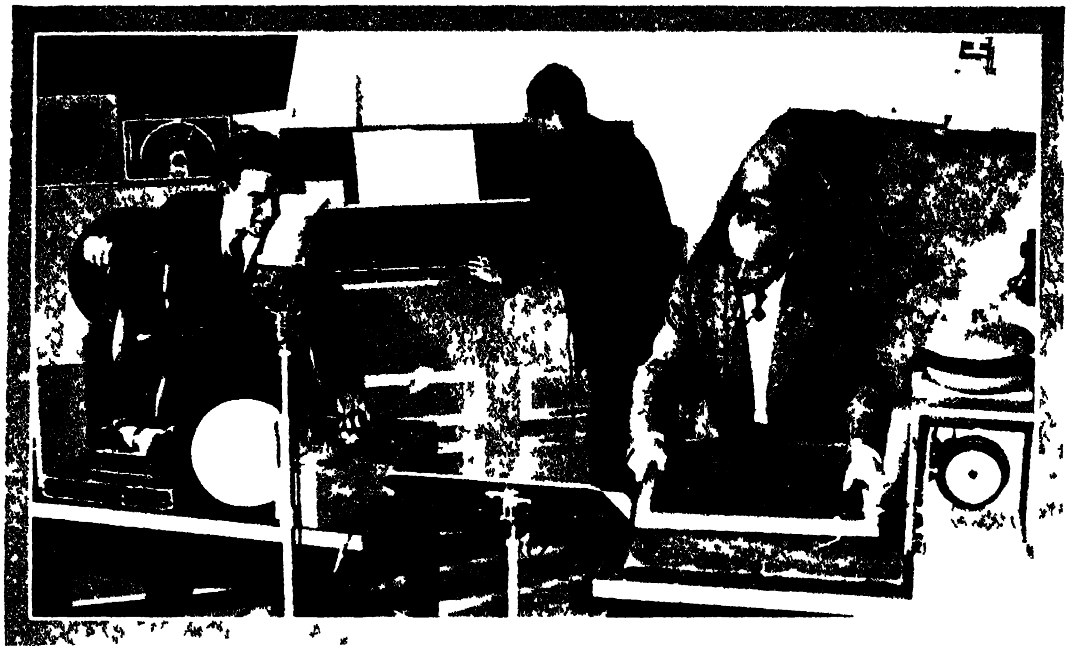
From this control room a rehearsal is criticized as it is picked up by the microphones in the studio. Only in this way can a finished performance be given, for inside the studio the directors hear the actual sounds produced by the performers, and cannot know what the microphone is reporting. Our critic in the picture is signaling to the producer through the double, sound-proof window in front of him. When the program is broadcast to the public he will be joined by the producer, who will direct it from this point of vantage.

In a modern control room there are usually two important persons in charge of the broadcast. One is the engineer and the other is the producer, or production man. They correspond somewhat to a man and his chauffeur. The man knows where he wants to go and gives all necessary directions to the chauffeur, who manages the trip's mechanical side about which the owner of the car may well have only the barest knowledge. Both producer and engineer are highly important, and a well-balanced team can do excellent work. If an engineer is sensitive, he needs only a slight suggestion from a producer to achieve what both desire, a perfect performance.

It is the producer's business to run the broadcast from start to finish, from the moment it is first decided to put on a given broadcast to the moment when the performance is "signed off" at the program's end. And it is his responsibility to see that all the people involved in producing the program work harmoniously toward perfect achievement. Writers, actors, singers, musicians, conductors, announcers, sound effects, and the engineer as well, will all have to be marshaled to do their parts perfectly. The producer is the general of this army, and if he knows his business his army will do him credit.

The control room, then, is equipped with the complicated network of wires which make it possible for the engineer to mix his "broadcast punch." They run from microphones to tubes to the control knobs or dials, and then onward to the main control room, which is in contact with all the studios in a given station and which, in case the station is a member of a national network or hookup of several other stations, sees to it that the programs in question are going where they are scheduled.

Let us examine the first, or studio, control room a little more closely. Its size is relatively unimportant. It is large enough to accommodate perhaps half a dozen people, and is equipped with the cabinet and dials already mentioned. Before them sits the engineer, with both hands busy seeing that the right amount of volume from each microphone is going into the final broadcast. To report on



These are some of the devices that imitate natural sounds for the microphone Wind machines and other instruments imitate storms, surf, rain, and the rattle of a worn-out automobile A 6-inch sheet of cellophane judiciously crumpled will give the effect of a forest fire, and the crumpling of a smaller sheet will sound like ying eggs An airplane crash will sound very convincing if a fist is brought down sharply on a peach basket If a sheet of tin is properly shaken the microphone will pick up what sounds like the crash of thunder, though a skillful drummer seen at the rear in the picture will be necessary to simulate the thunder's roll Recordings played here by the man who stands second from the left will reproduce the noise of marching men, of traffic of passing trains of automobiles, and of barking dogs mewing cats grunting pigs, and crying babies though some studios rely on a skillful mimic to imitate the cries of animals and children Certain commonplace noises such as walking on gravel or the striking of a match are never imitated The microphone must have the real thing if the audience is to be convinced

this, there is a loudspeaker which faithfully transmits whatever happens in the studio The engineer and the producer can see into the studio through a huge glass window, which usually has double panes of glass and often triple panes, to make it soundproof They do not hear any of the performance directly All they can hear on the loudspeaker is what is actually being picked up by the studio microphones It is just what the public gets through its radio sets

The Birth of a Broadcast

It is now possible for the engineer and the producer to know whether there is too great a volume of sound from an orchestra or not enough from a singer's voice—or whether both are at fault Adjustments of this sort can be made in various ways A microphone dial may be turned a little to cut down the volume of sound, or the conductor of the orchestra may be asked to have his musicians play more softly, which of course will serve the same purpose Ideally such changes are better if made by the performers

It is of course necessary, in the course of rehearsal, for the people in the control room to communicate with those who are in the studio For this purpose the control room has a special microphone communicating with a loudspeaker in the studio But since performers in the studio are usually faced toward the control room, a good many directions can be conveyed merely by a motion of the hand

We have now discussed everything vital to a studio broadcast except the broadcast material itself—that is, the words to be spoken, the music, and any other features belonging to the finished performance Let us follow a popular coast-to-coast show from the moment of its birth as an idea to its final ap

pearance on the networks as a finished work of art.

We begin in the radio department of a national advertising agency, which has as a client a big corporation or manufacturing company. The company has decided to spend a large sum of money in making one of its lesser-known products popular. It calls the advertising agency and asks for ideas for a radio show which will achieve its end. The agency discusses the product and the type of people who will be likely to buy it. It is easy to see that if an expensive automobile is to be advertised the show will probably be quite different from one that advertises a loaf of bread or a breakfast food Everyone buys bread and breakfast food, and a show to advertise them well should be of a type that everyone will like.

Photo by WGN, Chicago

The chorus for a musical broadcast is having a separate rehearsal under the broadcasting station's choral director. Not until it is perfectly balanced and can come in at the appointed instant in the script will the chorus rehearse with the rest of the performers.

If our company which is to be "sponsor" for the show wishes to advertise a toilet soap, a certain amount of what in the trade is known as "glamour" will be desirable, and the agency may advise the hiring of a famous star of the theater or motion pictures. Let us say that the star is decided upon, and that she consents to do a series of radio plays for perhaps $1,000 or $2,000 a week her salary depending upon her reputation. Next, a writer must be found to write the "script"—the spoken parts, with full directions for producing the play. If his name has value he may be paid $500 for his work on each performance. Because "glamour" is required there must be music, and the advertising agency approaches a well-known conductor and commissions him to write a "theme," or melody, for the show—and perhaps to write special songs to go with his music. This "theme" will open the show and will identify the program whenever it goes on the air. The conductor's price for this special work—for all musical arrangements of his theme and for the twenty-four to thirty musicians he may ask to help him in playing or singing it— may total $1,500.

At this point a producer is put in charge and told to whip the program into shape. From his file of actors he selects the people who are to fill the various parts, and if he is undecided in any instance he may "hold an audition" and have a number of actors read the part in question before he makes his final choice.

With the parts cast, he confers, script in hand, with the station's musical director. They agree as to the music that should accompany the acting of the play, often adopting certain fruitful suggestions the author has made. The director then sees that the orchestra has its scores and knows its parts. Usually the first rehearsals of cast and orchestra are held separately. The producer schools his cast in the correct reading and timing of the dramatic parts and works out sound effects to duplicate the sounds the action calls for. At all times he is watching the length of the piece and trying to figure out its "rough timing" that is, the probable length of time the whole show will take on the air. If his play is too long he cuts it. If it is too short he may appeal to the author to add a few more lines or may ask the orchestra to fill in with music.

Meanwhile the advertising agency has been writing the "commercials"- the three or four minutes of advertising that goes with any half hour of network broadcast. Usually this time is divided between an opening com-

mercial and a closing commercial, both of which are included in the final script, along with full directions as to music and sound effects. The major networks limit very strictly the amount of time that may be given to commercials, for too much advertising destroys a listener's enjoyment.

Now the producer must choose his announcer, one whose voice and manner are suited to the type of material used in the show. Often actors and actresses are chosen to read the commercials.

At last the show is ready for a full rehearsal, in which the orchestra will be carefully matched to the dialogue and any rough places smoothed over. The final, or "dress," rehearsal is run off just as if it were a genuine broadcast, with the producer holding a stopwatch to see exactly how long it takes. For to save precious broadcast time and make it possible for individual stations to come into or leave the network at a given moment, every radio program is timed almost to a second. Often the dress rehearsals are recorded, so that the producer can study them over and over for defects, or decide how best to cut them down or lengthen them.

Meanwhile the agency's publicity department has been sending out stories and pictures to papers and magazines announcing the new show, and has done everything in its power to awaken interest. Tickets have probably been given out, so that there may be an audience to see the broadcast. For strange as it may seem, the "invisible audience"- the people sitting at home beside their radios - are much more likely to laugh if they hear an audience laughing in the studio.

When the radio theater opens its doors half an hour before the broadcast is to begin, hundreds of spectators are waiting to see the opening of the new show, with its famous star and its popular singers and musicians. When all are seated, the announcer usually greets the audience with a pre-broadcast speech, or "warmup."

The term "warmup" is properly applied to a speech welcoming an audience to a comedy broadcast. For it has been discovered that every audience must have a few minutes to "thaw out" before it is in a mood to break into laughter. Since it is necessary that the broadcast audience should laugh aloud, the warmup will probably bring on the chief comedians to tell a few funny stories and put the spectators in genial mood.

Finally, with the hour for the broadcast close at hand, a green light goes on, at least in most of the studios, to show that it is time to "stand by" the radio term which means that everyone must be quiet and that the performers must take their places ready to broadcast. Warning fingers, and usually an uttered "Quiet, please," tell the audience that the great moment is about to arrive. Then the red light flashes, the producer "cues in" the opening "salvo" whether music or speech and the show is on the air!

The producer, who has timed different sections of the show during rehearsals, now holds his watch and at intervals signals the performers to let them know how things are going. If applause is wanted, the producer and announcer simply hold up their hands before the audience and go through the motions of clapping. When there has been enough applause, the audience is signaled to stop, and usually does so in perfect cooperation. Of course the time for applause has been strictly rationed, along with the time for the rest of the program. But a good many things can go wrong, and a show can at any moment run behind or ahead of schedule. If there is music it can fill any time that may be left over at the end. And if the show has run too long, the announcer can break into the music at the end to bring the program to a close. If there is no music, the producer will have made provision for a last-minute cut by marking on the script a "tentative cut" section that can come out, if necessary, near the close of the play without interfering with the action. If the tentative cut has to be made, the producer indicates it to the performers by a vigorous and highly suggestive gesture. When he pulls his forefinger across his throat they know that he means "cut." But the invisible audience never is conscious of any of this tense planning. The voices cease, the music dies away as if the musicians had finished their score, and instantly the station announcer speaks in unhurried fashion to identify the program to which you have been listening.

BEHIND YOUR RADIO DIAL

How It Is That Bits of Glass and Metal Can Bring Us Music Out of the Air

LAST night you turned a knob on the front of a little box that sits on your living room table. It looks much like any ordinary box except for its knobs or little buttons and its brightly lighted dial. But when you turned the knob you heard a man speaking in London. He was telling you what had happened in Europe during the day. What brought his voice over thousands of miles of land and sea to that little box on your living room table?

As you already know if you have read our other articles about the radio, the sounds that came to you from London traveled on waves not waves of the sea or waves in the air but waves of electrical energy sent out from the broadcasting station where your reporter was speaking. We call them radio waves. They are not electricity, though an electrical current produces them. Just as our ears are receivers for sound waves and our eyes receivers for light waves, so a radio set is a receiver for radio waves. But in order to understand how it is all managed, we shall have to understand just what it is that the radio set has been built to receive.

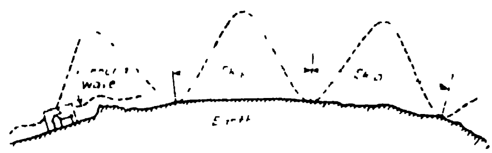


Photo from Understanding Radio McGraw Hill Co.

The dotted lines in our diagram show the two paths that radio waves are believed to take in traveling through space during the daytime. As you see, the ground wave does not travel far from the broadcasting station. But other waves from the same transmitter shoot into the sky until they reach the Kennelly-Heaviside layer of electrified air, which reflects them back to earth. They may be reflected back and forth in this way until they travel all the way around the earth. Very short waves, such as are used for frequency modulation broadcasts, go right through the Heaviside layer and on into space to be lost forever. For that reason, such broadcasts can be heard only a short distance from the station. In an ordinary broadcast the waves may not be picked up by certain receiving sets that are nevertheless near the station. That is because those sets happen to be located in a "skip space," where the waves have left the earth and have not yet been reflected back by the Heaviside layer.

Radio waves are impulses of electrical energy. While sound waves travel through air and through other ordinary matter, radio waves can travel through empty space and do not have to depend upon air or any other substance to carry them In this way they are like light waves, heat waves, x rays, cosmic rays, and other sorts of rays which you may read of in our story of physics, but radio waves are much longer than any of the others. All these various waves travel at about the same speed -186,000 miles a second, or the speed of light. Since the metric system of measurement is the one we use in measuring wave lengths, let us say, then, that they travel 300,000,000 meters a second--a meter being 39.27 inches. This speed is much greater than the speed of sound which will account for the interesting fact that we in America, sitting at home by the radio, can hear the voice of a statesman speaking in Europe before the sound of his words can reach the ears of the listeners sitting at the back of the auditorium in which the broadcast is made.

When radio waves travel along the earth's surface they may take two different routes. They may stay close to the ground or they may mount high above it. The ones near the ground never go very far, but the others can travel great distances -though not always without some disturbance, as we shall see. For at a height of from 70 to 200 miles above the earth is a layer of air that has become electrified as a result of the action of the ultraviolet rays of the sun. We call it the "Kennelly-Heaviside layer," in that way honoring the two men—one an American and the other an Englishman—who separately developed the theory of it. When ordinary radio waves strike the Kennelly (kĕ-nĕl'ĭ)-Heaviside layer

they are reflected back to earth. But at night the layer splits up into two separate layers, and it sometimes happens that a radio wave, breaking through the lower layer, goes bouncing along for some distance before it can break through to the earth again.

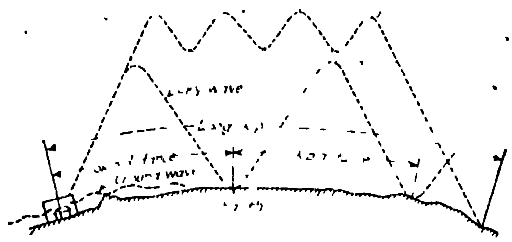


Photo from "Understanding Radio"—McGraw Hill Co

The behavior of radio waves at night is quite different from their behavior in the daytime. As darkness falls the Heaviside layer moves much farther away from the earth and splits into two separate layers. If a radio wave succeeds in penetrating the lower layer it may be reflected back and forth between the two layers for some time before it is able to get back to earth again. That is when we get "fading" in radio reception.

This will explain why a radio set sometimes fails to pick up a given station when a set still farther away can get the station without trouble. The unsuccessful set is located in a "skip space," which the waves missed when they were high up in the Kennelly-Heaviside layer. If the wave is reflected back to earth by the layer but gets here too late to reinforce the waves that are traveling along the ground, the sound that comes over the radio grows faint—we say it "fades."

Everyone has noticed that if the motor of the electric ice box starts to run while the radio is turned on, we hear a distinct noise over the radio. If an electric light is turned on, the radio clicks. During a thunder storm the "static" or unwanted noise that comes over a radio—may be so loud as to drown out the program. All this is because radio waves and what we know as "electromagnetic waves" are very close relatives. In fact without an electrical disturbance there could be no radio waves.

If you have read our account of electricity—and if you wish to understand the radio you will have to do so—you will know that whenever an electrical force is applied to a wire, millions of electrons are put into motion. If that force is the kind of electric current that most of us have in our houses—we call it an "alternating current," or "AC"—the electrons are set hopping back and forth at a tremendous rate, as fast as sixty times—or sixty "cycles"—a second. That rapid motion back and forth we refer to as oscillation (ŏs'ĭ-lā'shŭn). One may see the same kind of thing in a swinging pendulum. Current coming from a battery never oscillates. It flows along smoothly, as water flows through a hose. We call it "direct current," or "DC."

Unfortunately a current that oscillates sixty times a second swings back and forth too slowly to serve as a radio wave. The generator that sends electricity to our houses would have to produce a current in which the electrons swung back and forth, or oscillated, at least 100,000 times a second before the current could be used to send out radio waves. But the electrons oscillating in an ordinary electric current can and do send out electrical impulses. What we call "magnetic fields" are set up around them, and as those fields change with the running of the motor in the refrigerator or with the turning on of a light the disturbances are sent out into space in the form of electromagnetic waves, and travel in all directions at 300,000,000 meters a second.

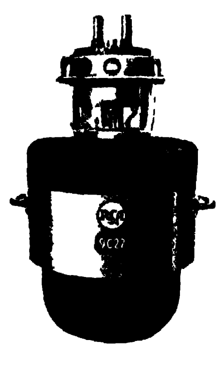


Photo from Radio Corp of America

Our photograph shows a radio transmitting tube, used to produce the rapid oscillations necessary for sending out radio waves in a broadcast.

If a generator could produce a current that would oscillate, or alternate, 100,000 times a second, such a current could be used to send out radio waves. There are several ways of making the electrons oscillate in this rapid fashion. We used to employ a device known as a "spark coil." Then we used a high-frequency generator. But to-day we rely on a vacuum (văk'ū-ŭm) tube. It looks like the vacuum tubes in your receiving set, only it is much larger and more powerful.

The reason why the waves sent out by the refrigerator can produce noises in the radio but not a tone is explained by the fact that they are not controlled in such a way as to make them reproduce sounds. In like manner electrical storms may produce waves that will interfere with regular radio waves that are traveling through space. In that case the radio waves either fail to reach your receiver or are distorted when they do arrive. Radio waves also show the effects of the time of day, of the coming on of night, of the appearance of sunspots on the surface of the sun, and of the distance and conditions through which they travel. Some radio waves travel better by day, others travel better by night. And some are much less affected than others are by the conditions we have just described.

You have watched the ripples of water move outward in ever-widening circles when a stone was thrown into a pond. Radio waves leave a wire in much the same way. They vary in length from a few meters to over 30,000 meters, but not all of those wave lengths are being used for radio broadcasting.

"We broadcast at a frequency of 1,000 kilocycles by the authority of the Federal Communications Commission," says the announcer. But what do those familiar words mean? If you will look at the dial of your radio set you will see that the numbers on it range from 550 to 1,600 kilocycles (kĭl′ô-sī′k'l)—or perhaps from .55 to 1.6 megacycles, a megacycle being 1,000 kilocycles. This means that all the stations to which you ordinarily listen are sending out radio waves which fall, as we say, within this range of "frequencies"—or oscillations per second. You will remember that an oscillation is referred to as a "cycle."

Now a kilocycle is merely a word for 1,000 cycles. So a station that is operating at a frequency of 1,000 kilocycles is merely a station that is sending out electrical impulses in which the electrons oscillate 1,000,000 times a second—or to put it in commoner terms, it is sending out 1,000,000 radio waves a second.

Photo by Bliley Electric Co.

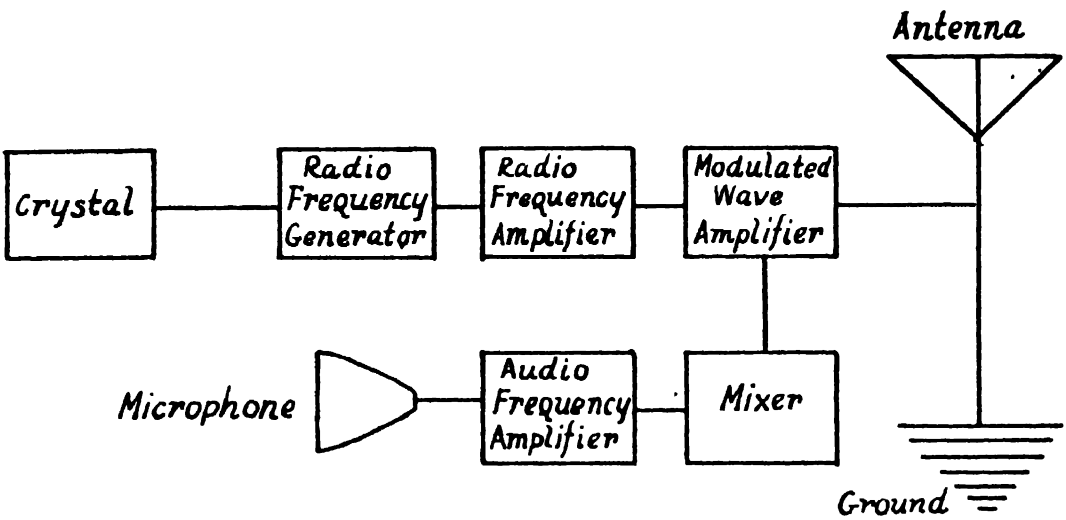
The even speed of the oscillations in a radio transmitting tube will be controlled by a quartz crystal. The crystal is really a vibrating body, set in motion by feeble electric currents generated in the transmitting equipment that it is controlling. The unvarying swing of the vibrations—and consequently the exact length of the radio wave sent out by the transmitter depends upon the dimensions to which the crystal has been ground. The grinding is so precise that a fine quartz crystal can hold the frequency of a given transmitter to within less than .005 percent of the intended wave length. In actual use such crystals are inclosed in a Bakelite body, or "holder," which also holds the necessary equipment for making the electrical connections. As you will see from the picture, the device, like the tubes in your radio, can be plugged into a socket.

What Is a Radio "Frequency"?

We know that radio waves travel at the same speed as light—186,000 miles, or 300,000,000 meters, per second. So if the 1,000,000 waves have traveled 300,000,000 meters by the end of a second, each wave must be 300 meters long—for 300,000,000 divided by 1,000,000 equals 300. In other words, 300,000,000 divided by the length of a given wave will always give you the frequency of the broadcast in kilocycles. The speed at which radio waves travel is always the same—the speed of light—but the length of their step varies.

It is much as it would be if two boys were tramping together to a ball park. They would cover the same distance and get to the ball park at the same time, but the shorter boy, because his steps were shorter, would have taken a good many more steps than the taller one. In terms of the radio, we might say that he had traveled at a "higher frequency."

Now let us see just how it is that a vacuum tube, a little contrivance of metal and glass, can send out waves that travel at high frequencies all the way around the earth in the fraction of a second. When you stretch a rubber band and pluck it to produce a sound, you will notice that it vibrates back and forth until it comes to rest. You will also notice that the distance through which the rubber band vibrates keeps getting shorter and shorter until the motion stops. In just the same way when an electric spark is created by a spark coil—that is, when the electrons, piling up on either side of the narrow gap in the electrical circuit, finally jump across the gap and make a spark—the elec-



This is a diagram, not a picture. It shows the various steps in broadcasting radio waves. The crystal holds the oscillating tube, or "radio frequency generator," to an exact rate of oscillation, so that the frequency of the radio wave will not vary and cause "interference" by wandering off the band assigned to it by the government. Those regular impulses are then amplified, just as the much slower audio frequency waves carrying sounds from the microphone are amplified. After the two kinds of waves have been combined the resulting waves are again amplified before they are sent to the antenna, which will broadcast them through space.

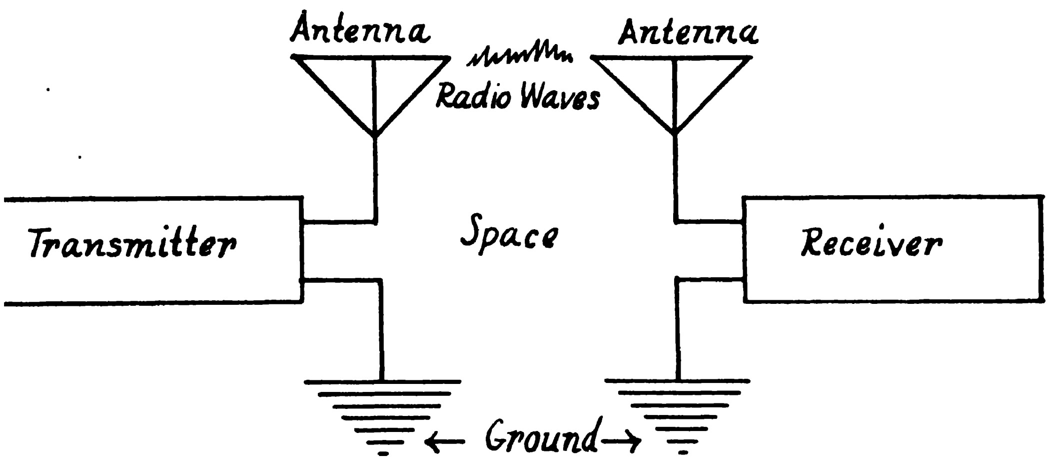
trical discharge shuttles back and forth, or oscillates, across the gap until it comes to rest. Of course we cannot see this oscillation because of the terrific speed at which it takes place. All we see is a flash of light. But with a delicate instrument called an oscilloscope (ô-sĭl'ô-skōp) we are able actually to see and study the form of an electrical wave. And on such an instrument the waves from our spark coil look like a series of curves rising and then gradually diminishing in height. Each group of waves will have been produced by one spark and will represent thousands of oscillations of varying height. Because the oscillations die down toward the end of each group, or wave, we call this a "damped radio wave."

Damped radio waves are too irregular to serve in transmitting speech or music, but they can be used to send noises which can be made long or short to represent dots and dashes. In this way they are able to transmit messages in the Morse code. That is the way in which these waves were first used by Marconi in his wireless telegraph.

Naturally, one at once wonders how, if we have a damped radio wave, we can make it carry speech and music—or, as the scientists say, convert it into an "undamped," or "continuous carrier," wave, which will be made up of vibrations that are all the same height. The answer is that a vacuum tube will do that for us. It is easy to generate high frequencies and to control the oscillations by means of such a tube.

But before the tube can send a broadcast out in the form of radio waves, the sounds must have been picked up in some way. First of all, of course, someone speaks or sings through a microphone, or perhaps music is played in front of it. A microphone is simply a very sensitive telephone transmitter which changes sound waves into electrical impulses, just as an ordinary telephone does. You may read all about the process in our story of the telephone. Those impulses—which we call "audio-frequency currents" because they vibrate slowly enough to be heard—are then sent into a radio tube which builds up, or "amplifies," them. The waves, or oscillations, are then much higher than before.

All the while that this is going on another tube will be producing radio-frequency currents—or, as we say, the tube is "oscillating." Those oscillations are much more rapid than the impulses coming from the first tube. They are moving back and forth at very high



This diagram shows the principal stages in communicating by radio. We must have a transmitter to produce the waves that will carry the broadcast, an antenna to start the waves traveling through space, an antenna to pick them up, and a receiving set that will utilize them in a way to make them yield the sounds of the broadcast. You will notice that both the transmitter and the receiver are connected with the ground.

frequencies, and will eventually produce the undamped carrier waves we have already mentioned.

Both of the currents, the audio-frequency and the radio-frequency, will now be sent into a tube which we may call a mixer. The mixer will combine the two currents, so that what comes out will be a high-frequency radio current changed, or "modified," by the low-frequency audio current. The result will be what we know as a "modulated" (mŏd'ū-lāt) current. That modulated radio current will be further amplified by other tubes and finally sent into a transmitting aërial a wire or wires, or perhaps a rod, stretched above the ground -where it will cause modulated radio waves to leave the wire and move through space.

It is the height, or "amplitude," of these waves which has been changed by modulation. Quite a different pattern has been given to them, corresponding to the sounds from the microphone that were registered upon the audio-frequency waves. It is that change in height which makes it possible for the outgoing waves eventually to reproduce, as well as may be, all the various qualities of the original sound. We say that the audio-frequency waves have been "impressed" upon the radio-frequency waves.

And now our radio program has been sent racing through space, borne by the modulated radio waves that we have just described. But that is only half the story. How are we going to bring the waves into our homes and change those silent, invisible impulses of elec-

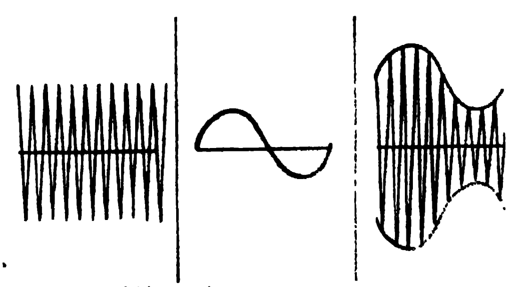


Photo by General Electric Co

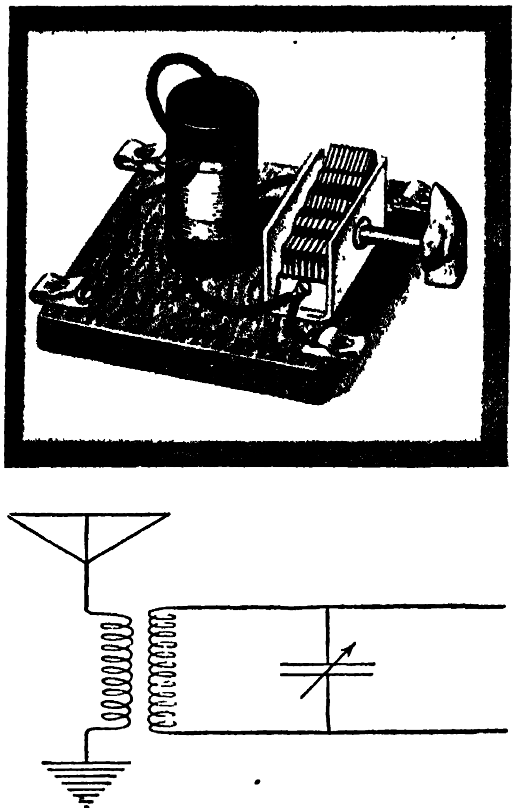
We do not know just what radio waves would look like if we could see them, but by means of diagrams we can give you an idea of what happens when a radio wave is made to carry the sounds picked up by a microphone in a broadcast. At the left above is the "continuous carrier wave" - the electrical impulse sent out from the radio transmitting tube that is rapidly oscillating during any broadcast. In such a current the electrons are hopping rapidly up and down, as is shown by the fact that their path in the diagram takes them both above and below the straight horizontal line, which indicates an interval of time as well as the direction in which the waves are traveling. In the center above is a diagram of an audio frequency wave. This is the wave that carries sounds from the microphone. As you will see, it is much slower than the carrier wave, for a single pulsation fills the same interval of time that is shown in the diagram at the left. The diagram at the right shows what happens to the carrier waves and the audio frequency waves after they have been "mixed" and are ready to be sent out from the aërial as "modulated carrier waves." You will notice that the frequency of the carrier wave is unchanged, but that its height or "amplitude"- - has been altered to fit the amplitude of the audio frequency waves, which will vary in shape according to the sounds to be transmitted.

trical energy back into the original sounds that were sent out at the broadcasting station? We shall do this by means of the receiving set that sits upon our table or stands against the wall.

You may have seen an experiment that is often performed with two violin strings tuned to exactly the same pitch. When one of the strings is played upon—that is, when it is set vibrating by a bow or by being plucked—the other string also begins to vibrate, for it "picks up" the vibrations sent through the air by the first string, and begins to move with them.

This is more or less what happens in a radio receiving set. When radio waves coming from the various broadcasting stations strike the aerial connected with your receiving set, they create oscillations just like the ones sent out from the broadcasting station. One of those oscillating radio currents will have to be selected from all the rest by your receiving set, and the others will have to be shut out, before you can hear a program. In other words, you will have to "tune in" to one of the currents.

When we say we tune in to a station we mean that we adjust certain controls on our receiving set in such a way that they will be

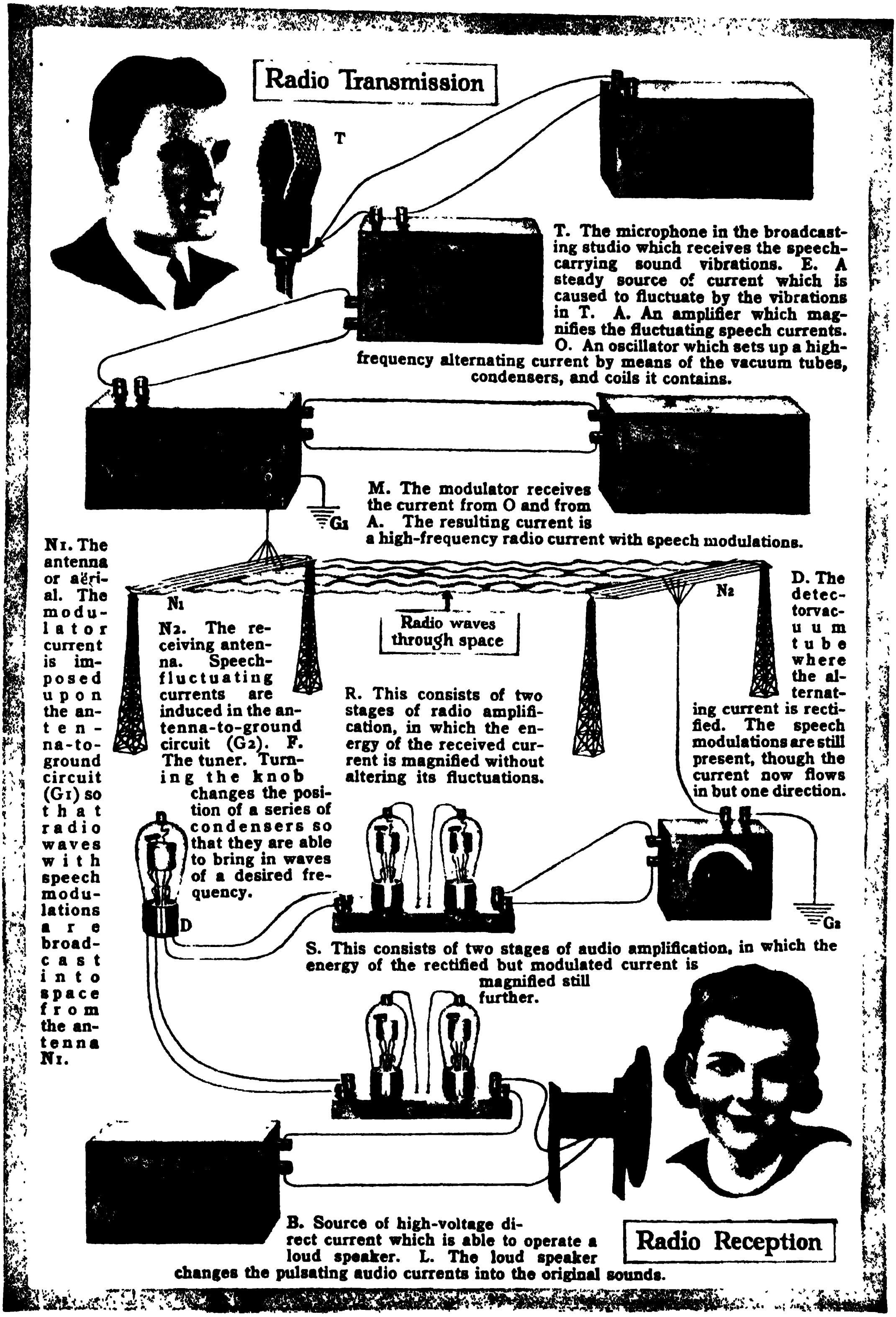


At the top above is a picture of the devices which make it possible for you to bring in a broadcast on your radio. Below the picture is a diagram which will make it easier for you to see how it all works. Your radio's antenna shown by the triangle at the top of the diagram —is the part of your receiving set that picks up the radio waves as they travel through space. The horizontal parallel lines at the bottom of the diagram represent the ground, with which the antenna should always be connected. The antenna coils—shown by the loops in the diagram and by the upright cylinder in the picture are two coils of fine wire wound on a cardboard cylinder. They act as a transformer and strengthen the weak currents that have been picked up. If your set is a powerful one an antenna will not be necessary for bringing in local broadcasts. But an antenna will always make the signals stronger, and is necessary for short-wave reception. Its length is of great importance for bringing in clear signals. Of course the waves from a great many different broadcasts will strike the antenna, and if we heard them all there would be nothing but a jumble of sounds. But a variable condenser shown at the right of the antenna coils in the picture and in the diagram by two parallel lines with an arrow across them— can be turned to adjust the set so that waves of only one frequency—that is, from a single broadcast—will be brought to your ears. When you turn the dial of your radio you are really adjusting your variable condenser.

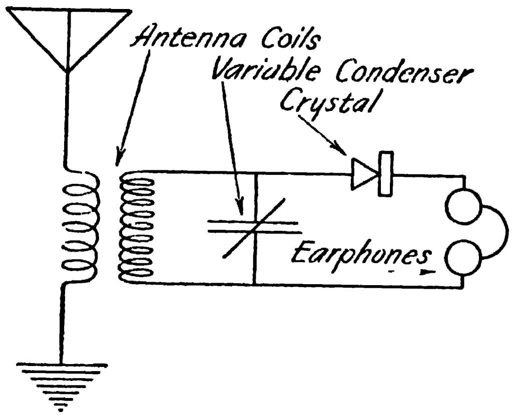
in perfect alignment with similar controls at the broadcasting station. The more perfectly we align these two sets of controls, the more accurate will be the tuning and the clearer and more perfect the "reception"—or the sounds the radio gives forth in reproducing the program. Let us examine those controls both in the transmitter and in our own set.

The frequency of the radio waves sent out by the transmitting aërial—the one that broadcast the program was controlled by the very careful adjustment of two different kinds of devices. One was a condenser and the other consisted of coils of wire. Those two devices controlled the frequency of the radio waves by controlling the frequency of the oscillating electric circuit from which the radio waves were broadcast. Our story of electricity will tell you about the part a coil plays in an electrical circuit.

A "condenser" is merely a device for storing up an electrical charge. You have probably amused yourself by shuffling across a woolen rug and then touching a metal lamp in order to see an electric spark shoot from your finger tip. You were robbing the woolen rug of electrons and were so overcharged with "static electricity"—elec-


Radio Transmission
T
T. The microphone in the broadcasting studio which receives the speech-carrying sound vibrations. E. A steady source of current which is caused to fluctuate by the vibrations in T. A. An amplifier which magnifies the fluctuating speech currents. O. An oscillator which sets up a high-frequency alternating current by means of the vacuum tubes, condensers, and coils it contains.
M. The modulator receives the current from O and from A. The resulting current is a high-frequency radio current with speech modulations.
G1
N1. The antenna or aërial. The modulator current is imposed upon the antenna-to-ground circuit (G1) so that radio waves with speech modulations are broadcast into space from the antenna N1.
N1
N2
Radio waves through space
N2. The receiving antenna. Speech-fluctuating currents are induced in the antenna-to-ground circuit (G2). F. The tuner. Turning the knob changes the position of a series of condensers so that they are able to bring in waves of a desired frequency.
R. This consists of two stages of radio amplification, in which the energy of the received current is magnified without altering its fluctuations.
D. The detector vacuum tube where the alternating current is rectified. The speech modulations are still present, though the current now flows in but one direction.
D
G2
S. This consists of two stages of audio amplification, in which the energy of the rectified but modulated current is magnified still further.
B. Source of high-voltage direct current which is able to operate a loud speaker. L. The loud speaker changes the pulsating audio currents into the original sounds.
Radio Reception

trons at rest—that an electrical pressure was created in your body. It was strong enough to push the extra electrons off into the lamp, which had fewer than your body had. You



In the simplest form of receiving set the listener hears the broadcast through earphones. The waves from the broadcasting station we call them "signals"- come in through the antenna and are strengthened by the antenna coils. With the aid of the variable condenser we are then able to select the signals we want to hear that is, we tune in to the desired frequency and pick up a given broadcast. But we still cannot hear it. In order to make those alternating "carrier" currents yield us sound we must change them into one-directional, pulsating, audio-frequency cu.rents. A galena crystal will do this, and so make it possible for us to hear the broadcast through the earphones.

could have discharged those extra electrons on to the cheek of another person provided that he had not been shuffling about on the rug.

The condensers in a radio set act in much the same way. All of them have two or more metal plates that are separated by some substance that is a poor conductor of electricity —air, paper, mica, wax. The plates are able to store up charges of electricity, just as your body did—the size of the charge depending upon the size of the plates, the distance between them, and the substance that separates them.

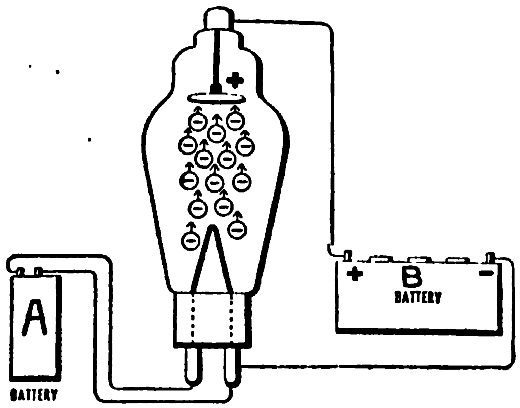
There are several types of condenser in your radio set. One type—the "variable condenser"—consists of two sets of thin metal plates separated by air. One set is stationary, but the other set may be turned back and forth in such a way that its plates will interleave with the plates of the first set—much as our fingers "interleave" when we start to clasp our hands. When you tune your radio set by turning the knob to a number on the dial, you are changing the position of the second set of plates in a variable condenser and thereby changing the "electrical capacity" of the condenser—that is, you are increasing or decreasing its ability to store electricity. By doing this you will be changing the frequency to which your set has been tuned. When the plates of the variable condenser reach a position in which the frequency of some transmitting station is reproduced, you will begin to hear the broadcast that station is sending out.

Tuning a radio, then, is simply a matter of adjusting a variable condenser to match some frequency that is being broadcast. Of course, that frequency must be within the range of your set—or, more exactly, within the frequency range of the particular coil in your set. We may say here that it is more common to speak of the "frequency" of a radio wave than it is to speak of its "wave length," though one depends on the other.

Now let us see just how those oscillating currents that you have just tuned in to and that are very much weaker than when they first left the broadcasting station, are strengthened and changed to the audible sound waves that will come out of the loud speaker.

When a radio signal the waves from a broadcast—enters a receiver it first of all must be made a little stronger. A transformer—or "antenna coil"—is used to give the weak current additional strength. The antenna coil consists of two coils of fine wire wound on a cardboard cylinder. One coil the primary—is connected between the antenna and the ground. The high-frequency currents surging from the antenna, through the coil, into the ground, and then back again, induce similar but more powerful oscillations in the larger, secondary coil. The secondary coil is in turn connected with the variable condenser used for tuning.

Just as singing a note into a piano will cause the string which normally gives out that note to begin vibrating, and just as a pendulum continues to swing as long as the pushes given it are timed properly, so the secondary coil and its tuning condenser will respond to only one frequency from all those appearing in the primary of the antenna

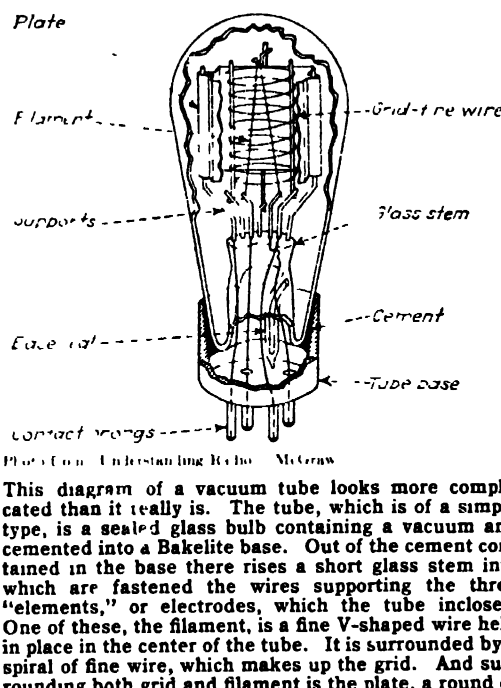


In this diagram you see the movement of electrons inside a two-element vacuum tube, or diode. An electric current from the A battery is heating the V-shaped filament standing up at the base of the tube. The heat forces the filament to give off electrons, which are negative charges of electricity. Here they are shown as little circles with an arrow on one side. Meanwhile the plate at the top of the tube is receiving a strong positive charge from the B battery, which is connected with the plate through its positive terminal and with the filament through its negative terminal. Attracted by the positively charged plate, the negatively charged electrons thrown off by the heated filament move in steady procession across the space between the filament and the plate. And this current is reinforced by electrons moving from the negative terminal of the B battery to the filament and then across to the plate. That circuit through the B battery and the plate is called the "plate circuit."

coil. The frequency which the secondary coil and condenser select and allow to flow through, depends upon the size of the coil and the electrical capacity of the condenser. With a few turns of wire and a condenser of low capacity, the combination will select and pass along a high frequency. Increase the capacity, and a lower frequency is passed. The tuning unit, consisting of the antenna coil and variable condenser, thus has the job of building up and selecting from the babel of radio signals the one we wish to hear.

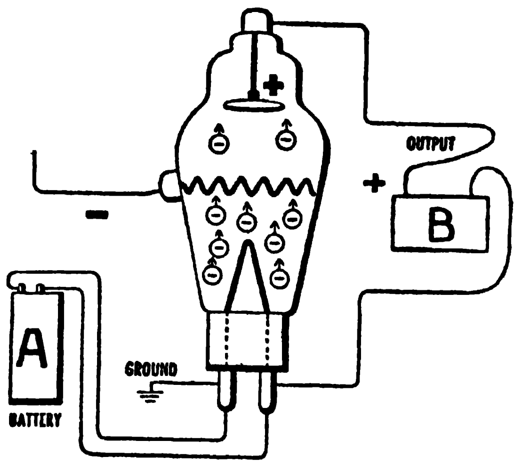
At first guess one might think that all one would need to do to make the modulated signal audible would be to connect a pair of earphones across the tuning condenser. But this would prove to be unsatisfactory. For when high-frequency alternating current passes through the magnet coils of the earphones, it causes the diaphragms (dī'à-frăm) to be pulled and pushed with equal force several hundred thousand times in one second. Our story of the telephone will explain this to you. Since the diaphragms are relatively large masses of matter and therefore are rather hard to pull or push, they cannot follow those individual pushes and pulls which are coming so rapidly. Instead they follow the average of all the pushes and pulls and so do not move at all.

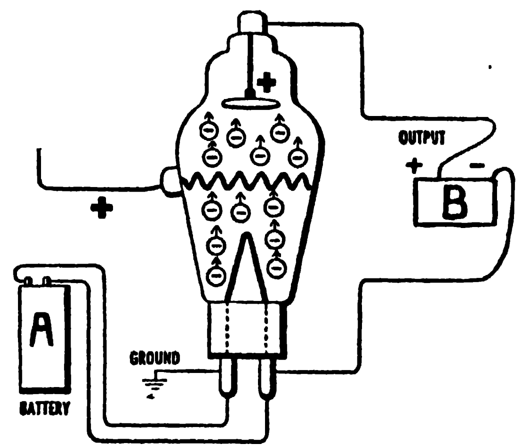
But if, by some means, we could prevent the current from reversing—if the earphones could get only the pulls without the pushes—then the diaphragm would follow the changes in the amount of pull. The motion of the diaphragm would then be the result of more or less pull upon it. Since the strength of the pull varies exactly in time with the modulating, or voice, wave, the diaphragm will move in accordance with



This diagram of a vacuum tube looks more complicated than it really is. The tube, which is of a simple type, is a sealed glass bulb containing a vacuum and cemented into a Bakelite base. Out of the cement contained in the base there rises a short glass stem into which are fastened the wires supporting the three "elements," or electrodes, which the tube incloses. One of these, the filament, is a fine V-shaped wire held in place in the center of the tube. It is surrounded by a spiral of fine wire, which makes up the grid. And surrounding both grid and filament is the plate, a round or rectangular tube that may be made of solid metal or of a fine mesh. You must imagine the plate as cut away on the side toward you in the diagram, in order to show the grid and filament inside it. And you must also imagine that the silver which coats the inside of the glass bulb has been removed on the side toward you. Wires running through the hollow contact prongs set into the tube's base make separate electrical connections with the grid, the filament, and the plate. Those prongs make it possible to plug the tube into a prepared socket. After the tube has been constructed, the air inside it is drawn out through the narrow tube labeled "base seal," and the tube is sealed to keep the air out.

those variations and so reproduce the sound impressed on the radio wave at the transmitting studio. Thus, in order to make radio waves yield up the sound waves—





Above are two diagrams of a triode vacuum tube. Like a diode tube, it has a V-shaped filament at its base and a plate at the top. But between them is a small wire screen or grating called the "grid" shown here by the zigzag line across the center of the tube. In the diagram at the left the grid has been given a negative charge. As in our diagram of a diode tube, the plate is connected with the positive terminal of a B battery and has a positive charge. The A battery serves to heat the filament. When the heated filament throws off its negatively charged electrons— shown as small circles with an arrow— they are, for the most part, repelled by the negatively charged grid and only a few reach the plate. The result is that the current through the plate circuit is greatly weakened or even cut off entirely. But if the grid is given a positive charge— as in the diagram at the right the stream of electrons flowing from the filament is greatly increased. For the grid helps the positively charged plate in pulling electrons from the filament. Since the grid is after all a mere network of fine wires, most of the electrons slip by it and reach the plate. In this way the flow of electrons through the plate and the B battery— that is, through the plate circuit is greatly increased. Small changes in the grid voltage— that is, in the strength of the charge on the grid will produce very great changes in the strength of the plate circuit.

which they carry in much the way that a horse carries a rider—we must change the radio-frequency "carrier" currents that are hopping up and down in the antenna wire into one-directional, pulsating, audio-frequency currents. This process is called "demodulation," or "detection."

There are several ways of "detecting" radio waves. A now outdated method uses a crystal of galena (gȧ-lē'nȧ)—that is, lead sulphide—to do the job. Such a crystal has an interesting characteristic. It will allow current to flow through it in only one direction. It is like a one-way street. Inserting the galena crystal in the circuit with the earphones keeps the current from hopping back and forth. The current through the earphones then becomes varying direct current, varying in time with the voice or music that is being broadcast. This kind of current then makes the vibrating diaphragm reproduce the original sound.

But the crystal detector is not very satisfactory. The user generally has difficulty in finding a sensitive spot on the crystal—one that will accomplish detection, or bring in the broadcast he is tuning into. Furthermore, those sensitive spots after a time cease to be sensitive, and then it is necessary to shift the contact to another part of the crystal. The most reliable method of detection, and the one most frequently used in modern radio sets, employs a vacuum tube and is called "diode detection."

A radio vacuum tube is like an electric-light bulb except that other metal elements have been added inside the bulb. The simplest form of tube is the diode (dī'ōd). It is a sealed glass bulb containing a vacuum and a filament, or wire, which has an electrical connection through the wall of the tube. Opposite the filament is a small metal plate, also with an electrical connection through the wall of the tube. When the filament is heated by an electric current from a battery—called the A battery—it gives off electrons, which of course are negative charges of electricity. Many of the electrons return at once to the filament, for they are attracted by the protons (prō'tŏn), or positive electrical charges, which helped to make up the atoms from which the electrons have been wrenched loose.

But some of the electrons never get back. A certain number drift over to the metal plate. If the plate has been connected with a wire going to the filament, the electrons will set up a very faint electrical current between the plate and the filament.

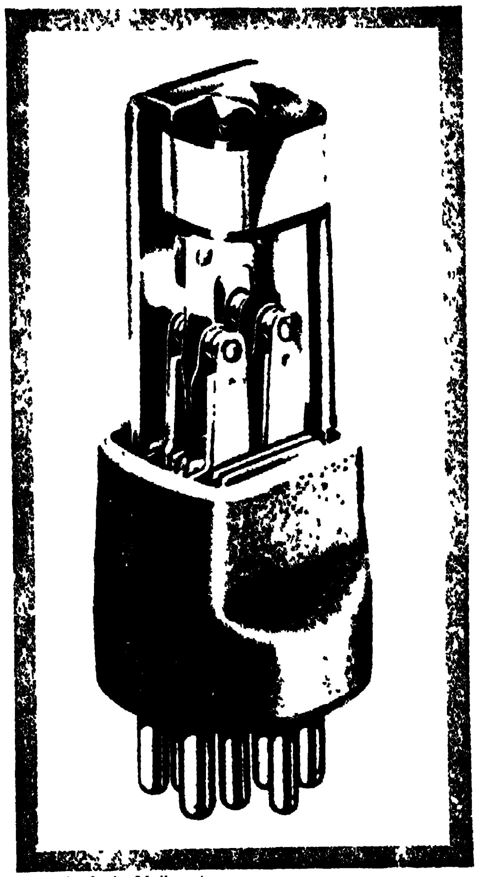


Photo by P. R. Mallory Company

A vibrator, shown here, must be used in a receiving set that depends upon batteries for its source of electricity. So you will find it in radios used in airplanes, automobiles, ships, and many farmhouses. It steps up a low-voltage direct current coming from the battery to a high-voltage alternating current, which must then be rectified.

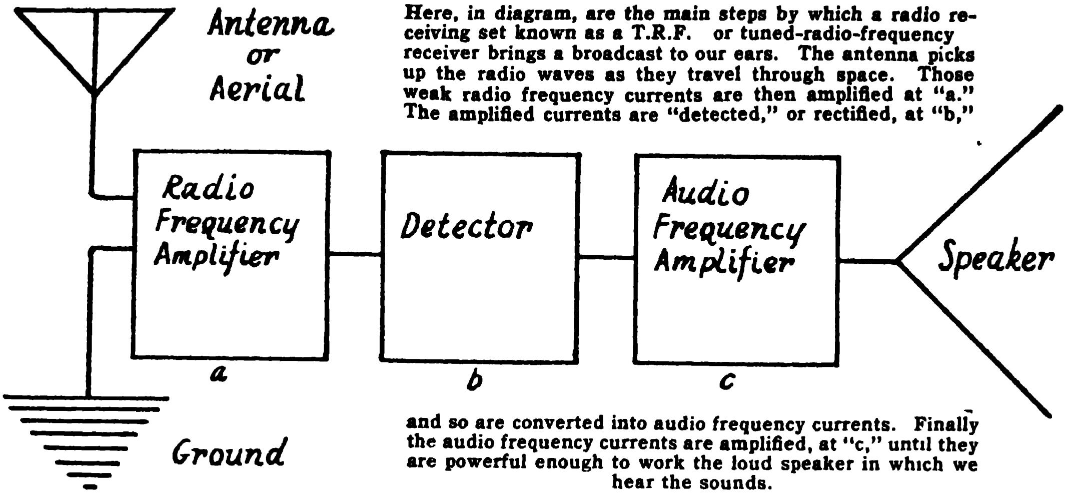
Now if we can give the plate a strong positive charge from another battery and at the same time provide more electrons for the filament, we can overcome the attraction of the electrons left on the filament and draw all the wandering electrons to the plate. This second battery called the B battery is put into the circuit of the vacuum tube in such a way that its positive terminal is connected with the plate while its negative terminal connects with the filament. Then, when the filament is heated, a steady stream of electrons will move from the negative terminal of the B battery to the filament, across the space in the tube between the filament and the plate, and then from the plate back to the positive terminal of the B battery. This circuit in which the electrons from the B battery flow, is called the plate circuit.

It is important to notice what would happen if the B-battery were connected in reverse. The plate would then be made negative and the filament positive. Electrons would be unable to leave the filament because of its high positive charge and there would be no flow of current in the plate circuit. Let us follow this idea one step further. If alternating current were applied across the filament and plate of a vacuum tube, what do you think would happen? Each time the plate was positive and the filament negative, a current would flow. But as the alternating current reversed and the plate became negative and the filament positive, the current in the plate circuit would cease to flow. This tube containing plate and filament—the diode tube—acts like a "valve," allowing the current to flow through it in one direction but not in the other.

You will remember that the galena crystal serves as a detector by permitting current to pass through it in only one direction. By substituting a diode vacuum tube for the crystal, we accomplish the same purpose and are able to get more reliable detection

Both the galena and diode detectors do their job of making it possible to hear low frequencies carried by radio-frequency waves. But they do no more The amount of energy which is put into the earphones of such receivers is simply the energy picked up by the antenna – an unbelievably small amount. Voltages set up in receiving antennas are no larger than a few millionths of a volt. The problem then is to take these tiny currents and magnify them.

The "triode" (trī'ōd) vacuum tube is used to amplify signals of both the audio- and radio-frequency types. The triode has a third element placed between the filament and the plate. This third element, which consists of a small wire screen or grating, is called the "grid."



Here, in diagram, are the main steps by which a radio receiving set known as a T.R.F. or tuned-radio-frequency receiver brings a broadcast to our ears. The antenna picks up the radio waves as they travel through space. Those weak radio frequency currents are then amplified at "a." The amplified currents are "detected," or rectified, at "b," and so are converted into audio frequency currents. Finally the audio frequency currents are amplified, at "c," until they are powerful enough to work the loud speaker in which we hear the sounds.

If we give the grid a positive charge we can greatly increase the stream of electrons flowing from the filament to the plate. Electrons are drawn to a positive grid, but because the grid is just a network of fine wires, most of the electrons pass right through a. I move on to the plate. If the grid is negatively charged, most of the electrons will be turned back to the filament and the flow of current in the plate circuit will be greatly weakened or even shut off. The important feature of the triode lies in the fact that since the grid is so much closer to the filament than the plate is, small changes in the numbers of electrons on the grid produce great changes in the plate-circuit current. This is the secret of the radio amplifier, for if we put a feebly varying voltage on the grid of a triode, a stronger current varying in time with the weaker current appears in the plate circuit.

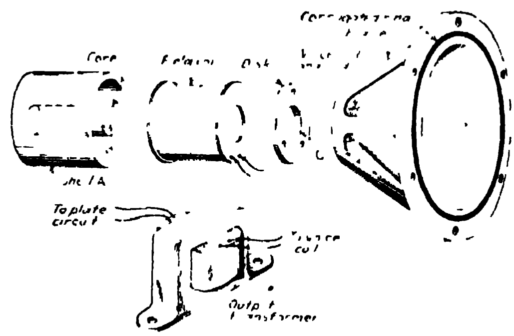


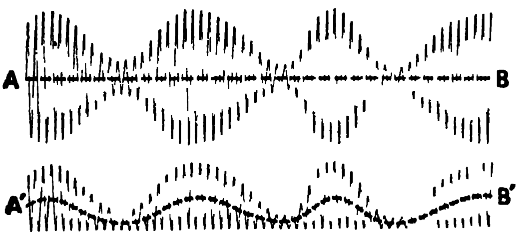
Photo from "Understanding Radio"—McGraw Hill Co.

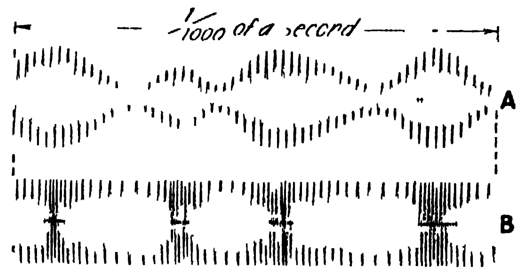
These are the parts of a dynamic loud speaker. The field coil, consisting of thousands of turns of fine wire, fits inside the shell, A, and over the iron core, B, in the center of the shell. These two pieces form an electromagnet. The iron disk, C, fits over the end of the shell, with the core protruding a very short distance through the hole in the center of the disk. There is just room for the voice coil– at the narrow end of the cone to fit over the end of the iron core, between the core and the disk. Fixed in an open metal frame is the paper cone, with corrugations pressed into the paper around the cone's rim, so that the cone can move back and forth freely as currents flow through the voice coil. The "spider" a metal or fiber disk with three curved arms holds the voice coil squarely in the center of the hole in the disk, so that it will not rub against either the iron core or the disk. The output transformer which contains two coils of wire with an iron core –will step down the voltage of the current from the plate of the audio tube before the current is sent on to the voice coil.

If we then add to our diode detector a triode amplifier, we can increase the volume of the received signal. The "coupling" of two vacuum tubes was formerly done by a transformer, but in modern radio sets fixed condensers and resistors carry the signal from one tube to the next. Several "stages" of amplification can be added in this fashion.

The A and B battery currents need not come from batteries. By certain circuit arrangements current from the house lines can be made to supply the necessary voltages.

The A current in a vacuum tube has only one duty— to heat the filament. But when it is an alternating current, it causes a hum in the set, and that of course mars the reception. To overcome that hum the filament is surrounded by a chemically coated tube called a cathode. In one of these "cathode tubes" it is merely the duty of the

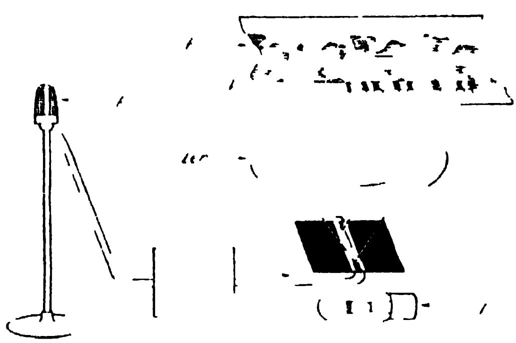


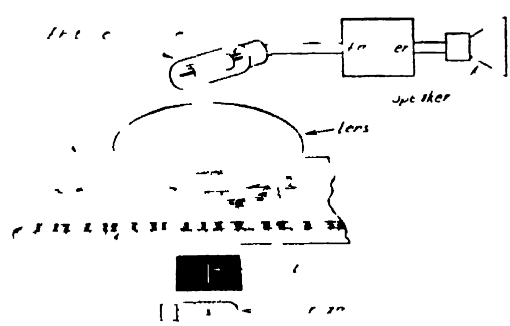


Above on the left is a diagram of a modulated radio wave. Such a current, if put directly into earphones, would produce no sound, for the diaphragm in the earphone would be pushed as hard as it was pulled and so would remain stationary. We have indicated this fact by the straight dotted line AB, which indicates the average of the pushes and pulls.

The lower diagram on the left shows a radio wave that has been detected, that is, a wave that we can hear. You will notice that the lower half of the wave has been canceled out and that the average is now represented by the wavy line A' B'. If a telephone receiver were plugged in on such a current its diaphragm would be pulled back and forth with varying force, and consequently we should be able to hear the sounds carried by the wave.

Above on the right is an amplitude-modulated wave. Here it is the *strength* of the wave that has been changed by the voice or audio frequencies. It has not yet been detected. Below (B) is a frequency modulated wave. In this case it is the *frequency* of the wave that is changed by the voice or audio frequencies. This is the type of wave used for what is known as FM reception.





The diagram at the left shows how sound is recorded on a film. First the sound is converted into a varying electric current by the microphone. The amplified current is then sent into two ribbonlike wires. The resulting magnetic field around each of these wires will cause them to repel each other. As the current varies, the extent to which they repel each other also varies, and this in turn causes a variation in the width of the slit between the wires. Those variations in the slit in turn cause variations in the amount of light focused on the edge of the film by the lens.

The diagram at the right will explain to you the process by which sound film is "read," that is, converted back into sound. Light from the exciter lamp at the bottom of the diagram—is sent through a narrow slit. The resulting narrow ray of light is then thrown on the sound track and illumines a small section of it. After the ray of light passes through the sound track it is focused by a lens on a photoelectric tube. In this way variations in the blackness of the sound track affect the brilliance of the ray of light, which in turn affects the strength of the electrical impulses flowing through the photoelectric tube. In other words, the variations in the sound track have been converted back into variations in electric current. Those variations in the current will now be turned into sound after the fashion we have described in this article and will be heard through the loud speaker.

filament to heat the cathode, which in turn will give off the electrons.

The construction and use of vacuum tubes belong to what is known as the science of electronics (e lĕk trŏn'iks), which has to do with the behavior of electrons when they do not form part of an electrical current or electrical charge.

In the older and simpler radio sets the sound came to the listener through earphones. But in a modern radio set the weak "signals"—or sounds—that could be heard only through the earphones are magnified by a loud speaker until they can be heard throughout a large room. This is managed by making certain changes in the simple set we have just described. Instead of sending the currents from the aerial directly into the grid of a tube that will rectify them, we first send them into the grid of a triode like the one we described first, one that will merely amplify the currents without changing their character. This tube is called a radio frequency amplifier.

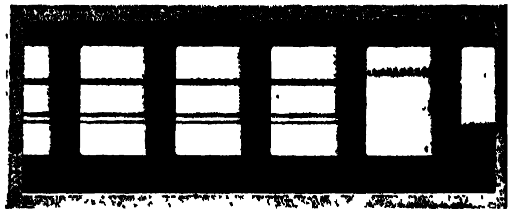
The plate of the radio-frequency amplifier then carries strengthened currents into a diode detector, which will have only to demodulate them—that is, change them into audio-frequency currents.

Now if we feed this detected or rectified current to a third tube—the "power amplifier"—which can amplify the audio frequencies, we shall finally be able to produce strong currents pulsating at a low frequency. Such a current can reproduce sounds in a loud speaker. The second tube will be coupled to the third by means of a transformer, or perhaps in other ways. And in a powerful set more than one tube may be used to amplify the radio-frequency or audio-frequency signals. Large audio-current amplifiers, such as boom out the line of a game in a ball park, use several tubes to amplify the audio currents, which come in through a microphone.

Tremendous strides in the designing of radio tubes have given us the excellent, rugged product we have to-day. Two or more tubes may be built into the same glass envelope, in this way saving space, material, and cost. Some modern tubes have several grids instead of just one. Increasing the number of grids increases the control we have over the flow of electrons. Multi-element tubes—that is, tubes containing, for instance, a number of extra grids—generally operate on the same principle as the triode but are particularly fitted to perform certain jobs in the receiver or amplifier.

At last we have brought the radio currents to the loud speaker, which will take the final step and turn them into sounds that can be heard everywhere in the room. The loud speaker in your receiving set is probably a "dynamic speaker." It consists of two main parts—1) a powerful electromagnet which has its iron core close to, but not quite touching, the narrow end of 2) a paper cone. It is the movement of this cone which produces the sound waves that we hear.

The cone is cemented at the large, open end to a frame which is tightly screwed to the cabinet that holds the set. A strip of felt or leather is pasted to the rim of the cone to make good contact with the board to which it is screwed, for that board will act as a sounding board. A small coil—known as the "voice coil"—is wound around the narrow end of the cone, and receives its current from a transformer—known as the "output transformer"—which couples it to the plate of the audio-amplifying tube. In other words, the voice coil is receiving the currents that were originally brought in by the aerial. The larger coil—the one that has an iron core—receives its current from the house current. Sometimes a strong permanent magnet takes the place of the larger coil. When a magnetic field is produced in the large field coil, the small voice coil moves somewhat as coils of wire move in a motor. And when the voice coil receives audio-frequency currents from the output transformer, it causes corresponding fluctuations in the magnetic field around it. Those fluctuations start vibrations in the paper cone, and the vibrations in the cone produce sounds.



The above photograph shows a short section of the sound track on a moving picture film. Those dark lines on the white spaces will be turned into sound.

Between 1935 and 1940 Professor Edwin H. Armstrong of Columbia University developed his system of broadcasting which is known as "frequency modulation"—or "FM." The waves he uses are quite outside the range of those used in the ordinary radio broadcast, so likely to be noisy. They range from 88 to 108 megacycles. Each FM station has a channel 200 kilocycles wide, which does away with interference. But more than that, the channels of the ordinary stations are too narrow to allow all the tones of a broadcast to be transmitted. A keen ear will pick up vibrations at frequencies ranging from 16 to 20,000 vibrations per second. But the standard broadcasts can transmit over a range of only 5,000 vibrations. This means that much of the quality of a tone is lost. FM, with its wider channel, can preserve the true quality of the sounds that are sent out from the broadcasting studio.

More important still, the radio wave used for FM is different from an ordinary radio wave. Frequency modulation does not change—or modulate—the amplitude of a radio wave when it changes that wave in order to make it carry sounds. Instead, it changes the wave's frequency. A loud sound, for instance, requires a higher frequency than a low sound. Waves of this kind are not interfered with by waves that cause "static"—that is, by waves sent out by storms or by other kinds of electrical equipment.

Neither does a frequency modulation broadcast suffer from fading. The waves it uses are so short that the ones shooting into the sky go right through the Kennelly-Heaviside layer and never are reflected back to earth. In other words, only the ground waves ever reach the receiving set. But this has a great disadvantage. All radio waves travel in straight lines. The only reason why an ordinary broadcast can be heard all the way around the curving earth is that the waves are reflected back by the Kennelly-Heaviside layer. Since FM waves are never reflected back, they cease to be heard when the earth curves away from the straight path they are following. This means that an FM broadcast can be heard only from 50 to 100 miles from the station. It must then be re-broadcast, if it is to have a large audience.

A receiving set for FM broadcasts is very much like a common superheterodyne receiver with some special features added. A superheterodyne (sū′pẽr-hĕt′ẽr-ō-dīn) receiver modifies the frequency of the incoming signals before it amplifies and detects them. An FM set adds a "limiter tube" to filter out noise and currents from ordinary broadcasts that will creep in along with the FM currents, and besides this has a "discrimination tube" to change the frequency variations to audio variations. The set will be provided with a special loud speaker because the audio currents are of a higher frequency than they are in ordinary sets.

At first glance this might be taken for a view of some new kind of smokestack sending out smoke. Actually it is an FM transmitting antenna that is being subjected to man-made lightning bolts of 110 million horsepower. Because they are so vulnerable to it all antennae must be made resistant to lightning.

Photo by RCA

Reading Unit No. 13

SENDING PICTURES THROUGH THE AIR

Note: For basic information not found on this page, consult the general Index, Vol. 15.

For statistical and current facts, consult the Richards Year Book Index.

Interesting Facts Explained

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The marvels that science can do, 10–123

What the word "television" means, 10-123

How men tried to make electric currents carry light as well as sound, 10 124

How the photo-electric cell and the vacuum tube helped television, 10-124

How television does for light what the telephone does for sound, 10 124-26

Things to Think About

How can television make life more interesting?

What does a photo-electric cell do?

How are photographs cabled across the ocean?

Why can we not send pictures just as well as we send sounds?

Picture Hunt

How can we get a television image from small points of light? 10 124-25

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Compare the wonders of television with the remarkable things that can be done with X rays, 10 125, 492-95

Summary Statement

Television has made vast progress and can bring us pictures of many sorts of events taking place at a distance. Improvements are still coming and many more marvels lie in the future.

From this control room in one of our large television broadcasting studios programs go out daily over the air. The young woman in the foreground is the program producer. In the center is the camera monitoring desk. And in the background is a view of that part of the studio which will appear in the broadcast.

SENDING PICTURES *through* SPACE

This Story Will Tell How Television Lets Us See Certain Things Hundreds of Miles Away, and How We May Some Day See Many More of Them

SOME day when you sit down to your telephone and call up your friend a mile away, or a hundred miles away, you may see him as he takes down the receiver and says "Hello!" You may watch him smile as you say you want to bring the car around and take him for a spin, and you may notice his taking out his watch to see how soon you will get there. You may look to see whether he will have to dress before you arrive. In a word, you may see your friend, and watch everything he does, just as well as you now hear him.

Already people who own television sets may sit by their radios and watch a baseball game, see the inauguration of the President of the United States, or enjoy a concert, play, or an opera put on in the studio or televised from the stage on which it is taking place. There are a large number of television transmitting stations over the country, and manufacturers are all the while making receiving sets better and cheaper. Eventually we shall probably be able to *see* anything that we can now *hear* by telephone or radio. For the word "television" means only "far seeing."

Interesting Uses of Television

But there are other things that television can do for us—perhaps more important than giving us interesting programs. By means of a device known as Ultrafax, which combines radio, television, and photography, it can send 1,000,000 words a minute over a whole continent. Telegraphy has never done anything like this.

In modern warfare television will play a part in guiding missiles and planes to their targets. We do not know just how this is done, but we know that it is happening. For just as the proximity fuse—installed in the nose of bombs in World War II—is a very, very tiny radio sending and receiving set, in the same way a television receiving set may be installed in a bomb and send or receive pictures that will help the missile on its course toward the target.

Photos by Bell Telephone Co

"Telephoning a photograph" sounds very strange, but that is just what happened to the picture shown above. At first it was a mere blur, but finally it developed into a clear picture.

The idea of television is not so very new. A good many years ago a German named Nipkow patented a machine for sending pictures over the wire. His idea, and indeed the whole idea behind television, was that if an electric current can be made to carry sound, it can be made to carry light as well; and it is light that makes a picture, as anyone with a camera or with two eyes must know. At bottom his machine was made on the right lines; but it could never be successful because the instruments of his day were too crude for the fine work that had to be done to send a picture that would be satisfactory.

In 1923, when a Scotsman named John Logie Baird went to work on the problem, he had two new inventions to help him —the photo-electric cell and the vacuum tube. With these at his command, he followed the main idea of Nipkow to much greater success, and it was not long before people were seeing pictures of things happening far away. By 1926 such pictures were shown before the Royal Institution in London. In the next year pictures were shown in Washington of events in New York; and one year later still Mr. Baird sent some pictures in color across the Atlantic. In 1930 the first television play was given in Schenectady, N. Y., and the actors were seen and heard perfectly. In 1932 some people in London saw the finish of the Derby, the famous English horse race at Epsom Downs.

Photo by Bell Telephone Co

Here you see the first public demonstration of television. Mr. Walter S. Gifford, president of the American Telephone and Telegraph Company, is talking to and at the same time *looking at* Secretary Hoover in Washington.

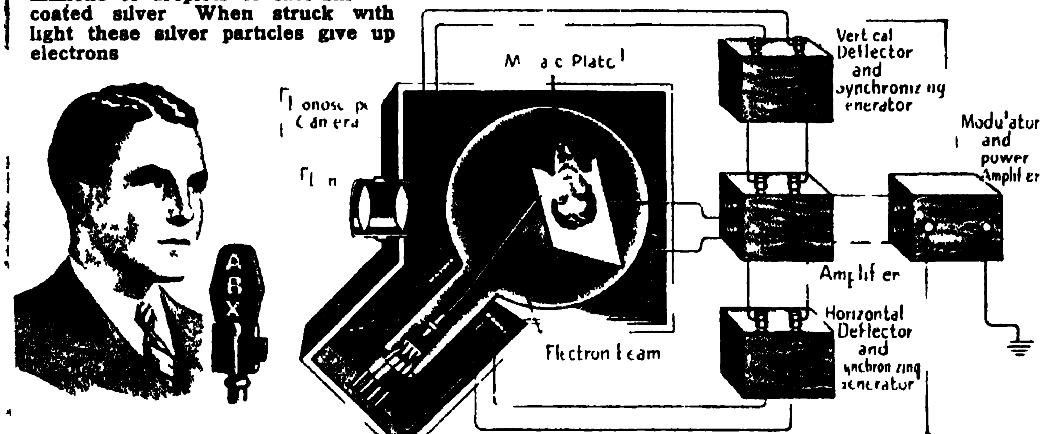
We can give some idea of the way modern television works. First of all, how does your telephone work? It does not really carry sounds over a wire or through the air. It carries nothing but electric current. The sounds at one end of the telephone set up vibrations, these act on the current running to the other end, and there the current sets up the same vibrations, next your ear, those vibrations reproduce the sound that made the ones at the first end, and you hear them. You seem to hear your friend's voice, a little altered. What you really hear is a reproduction of the sound of his voice.

Now television does for light what the telephone does for sound. It catches the light from a scene at one end, makes this set up vibrations that go over a wire or through the air, and then makes the vibrations reproduce a similar light at the other end to form a picture of the scene with which we started. Then you seem to see the scene, just as you seemed to hear the voice. What you really see is a reproduction of the scene. If that is all, why should it be harder to send a picture over the air than the sound of an orchestra? The answer is that pic-

The man's image is focused by the lens on the light-sensitive plate a mica sheet dotted with millions of droplets of caesium-coated silver When struck with light these silver particles give up electrons

Television Transmitter

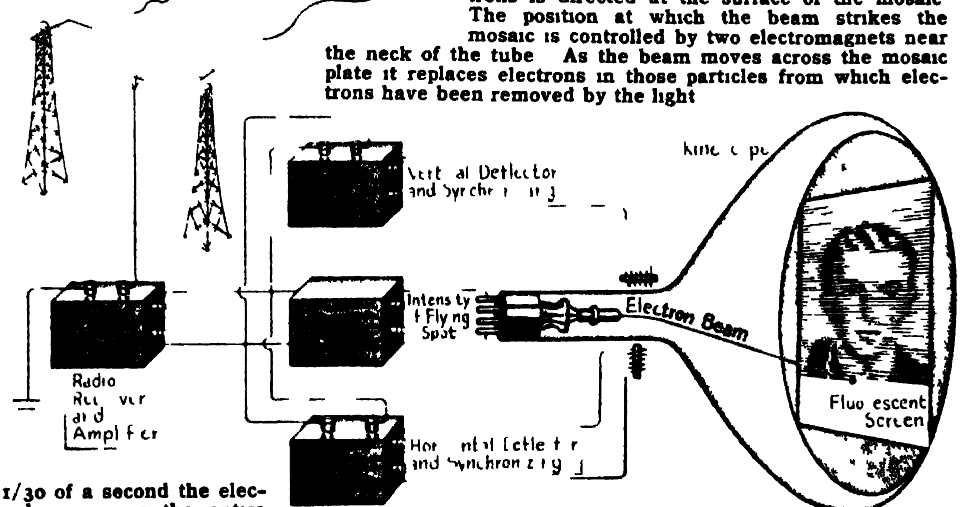
While the man at the left speaks into the microphone, his image is broadcast by television



Those areas of the image which have been struck by light contain droplets from which electrons have been stripped The brighter the section of the image, the greater the number of electrons knocked out Thus millions of silver particles are waiting their turn to go on the air to report as to the brightness of their section of the picture

The mosaic plate is inclosed in a vaccum tube.

Inside the iconoscope is a source of cathode rays—an electron gun The stream of electrons is directed at the surface of the mosaic The position at which the beam strikes the mosaic is controlled by two electromagnets near the neck of the tube As the beam moves across the mosaic plate it replaces electrons in those particles from which electrons have been removed by the light



In 1/30 of a second the electron beam scans the entire image by moving across, dropping a little, and then moving across again Every time it strikes a silver particle that is receiving light from the man's head, a radio signal is flashed through space The transmitter thus translates the picture into electrical pulsations which are then broadcast

Television Receiver

A radio receiver picks up the electrical impulses sent out by the transmitter They are amplified and sent into the kinescope (kĭn ē-skōp), a cathode ray vacuum tube containing a window of fluorescent material

The fluorescent window glows greenish white wherever the beam strikes it Electromagnets swing the beam in step with the beam in the iconoscope The incoming signal varies the intensity of the moving spot so that it traces out a pattern in light exactly like the image on the mosaic plate

tures can be very complicated things. For example, look carefully at a picture of a crowd of people or of all the players doing different things on a football field. The picture is complex, not because the people are so numerous but because the varieties of light and shade are so numerous. For what we are really sending, as we said, is light; and to make the picture look at all correct, we have to send at one time a vast number of lights and shades. You will realize this, as any painter does, if you look at a friend's face as he sits by a window, and try to count the number of lights and shades in the different features of his countenance. Then imagine a whole football team in motion over a green field, under a blue sky with varying clouds, against a background of waving banners of many a hue in many a kind of light.

We cannot send all these sorts of lights at once in the same way we send all sorts of sounds. At one moment we may send every sound an orchestra is making, or almost every one. We cannot do that for light—the thing is very much more complicated, and takes far more clever and expensive machinery. We can send the noise of a whole crowd over the telephone about as easily as the shout of a single person; but to send the picture of a crowd is very much harder than to send the picture of one person in it.

How the picture is broken down, transmitted, and then reassembled can be better told by pictures than with words. If you will look at the diagram we have given and read the explanations, you will have a good idea of how we send an image by means of an electric current. But first you will need to read on other pages what we have said about electronic tubes.

When experiments were made in "stratovision" or the broadcasting of television programs from an airplane six miles high—it was necessary for operators to wear oxygen masks and heavy flying suits, as the one above is doing. For the only planes in use for such work were converted bombers. Later planes give the three members of the flight crew and the six radio technicians every comfort known to aviation. Stratovision makes it possible to send out nationwide broadcasts of television and frequency-modulation programs at a reasonable cost.

The television transmitting tube is generally either an iconoscope (ī-kŏn'ō-skōp) or an orthicon (ôr'thĭ-kŏn). The two tubes do not look exactly alike and one is slightly more sensitive than the other, but the basic principle is about the same for both. The heart of the television transmitting tube is a mica (mī'kȧ) plate upon which tiny droplets of metallic silver are deposited. Each droplet is separate from its neighbor, just as the tiles of a mosaic (mō-zā'ĭk) are separated by plaster. The silver droplets are coated with caesium (sē'zĭ ŭm). Each droplet is a miniature phototube.

The image that is, the object to be "telecast" is thrown on to the mosaic plate. The dark parts of the image do not affect the droplets in their sections of the plate. But droplets struck with light are forced to give up some electrons. Thus an "electron image" is built up on the mosaic plate. Starting from the top an electron beam is pulled across and back by electromagnets or charged plates situated at the neck of the tube. The beam scans the entire mosaic plate in 525 lines. For $262\frac{1}{2}$ trips the beam is pulled across the mosaic plate, each time dropping a little lower before beginning the next trip. When the image is scanned once, the scanning beam begins again. This time the beam scans

This scene in the control room of a big broadcasting studio will give you some idea of one of the final steps in sending out a television program. It is at these desks that the "mixing" is done. In other words, it is here that sound is matched to sight and speech and action are synchronized and sent out exactly together. In the upper left-hand corner is a glimpse of the studio where the broadcast is being enacted. Just below it are six pictures- or "frames"—that show what is about to go out over the air. The frame that is fourth from the left contains the television material that was ready to broadcast at the moment when our photograph was taken. The other frames contain material that is "coming up"—that is, they will be broadcast in turn, after the smiling face of the girl has been sent out.

between the previous lines. Another 262½ trips across and the whole image is scanned. The total of 525 lines of scanning is accomplished in 1/30 of a second.

What does this scanning do? As the electron beam passes each particle of sensitized silver it inquires, in its own way, as to whether or not electrons have been removed from the silver by light. If none have been knocked out, no electrons flow from the beam. If, however, the beam comes upon a particle from which electrons have been removed, the beam supplies the needed electrons and a signal is sent out over the air.

At the receiving end there is a similar electron gun producing a similar stream of electrons. This time, however, the electron beam is not directed against a mosaic plate. Instead, it strikes a screen of fluorescent (flōō′ō-rĕs′ĕnt) material at the far end of the tube—that is, a screen made of material that itself can emit light when it is exposed to certain kinds of rays. The electronic tube on which the television image appears is called the "kinescope" (kĭn′ē-skōp), or cathode (kăth′ōd) ray tube.

The electron beam in the kinescope is moved back and forth in exact step with the beam in the transmitting tube. The incoming signal, after being amplified, is applied to a negatively charged grid which normally prevents electrons from the "gun" from striking the fluorescent screen. When a signal enters the grid, however, it causes the grid to become less negative and so allows some electrons to strike the screen. This causes the screen to glow. As a result, light appears on the kinescope screen at ex-

When the usual methods of broadcasting are used, television and frequency-modulation programs will not carry beyond the horizon, for the radio waves on which they are transmitted travel out in straight lines and are not reflected back to earth. This great handicap has been partially overcome by relaying the broadcasts—of course at great expense. The sketch shown above gives you a profile view of such a relay. The program is being broadcast from the top of the Empire State Building in New York City—shown at the extreme left. Normally the program would be heard within only a narrow radius. But since it is starting from a point that is over 1,000 feet high it has a good deal wider horizon—so wide that it can be picked up by a relay station on top of a mountain 129 miles away. From there it is sent on to a large broadcasting station in Schenectady, New York—shown at the extreme right in our sketch. The station there rebroadcasts the program from its transmitter on a mountaintop 12½ miles away.

actly the same points at which the light fell on the mosaic plate. Since the intensity of the signal sent out varies with the amount of light striking a particular point on the mosaic, the kinescope can reproduce the varying degrees of shading in the original image.

To keep the kinescope electron beam exactly in step with the beam in the transmitting tube, the transmitter sends special "synchronizing" (sĭn'krō-nīz) signals. These signals have two jobs. They tell the kinescope electron beam when to start scanning a new line and when to start a new picture.

Photo by Westinghouse

Above, a television and frequency modulation radio program is being beamed from a ground station to an airplane 30,000 feet up, and will be broadcast from the plane. It will be picked up by receivers everywhere inside the large circle, which has a radius of 211 miles. Broadcasts direct from the studio would cover only the small circle, with a radius of some 50 miles.

TRANSPORTATION

Reading Unit
No. 1

PRIMITIVE LAND TRANSPORT

Note: For basic information not found on this page, consult the general Index, Vol. 15.

For statistical and current facts, consult the Richards Year Book Index.

Interesting Facts Explained

Man's handicap as a runner, 10-128

When man began to put burdens on the backs of his wolf dogs, 10-129

How North American Indians hitched dogs to a travois, 10-129

The amount of rice a man can carry while traveling, 10–130

Man as a beast of burden, 10-130-32

How Eskimos hitch dogs to their sleds, 10–130, 133

The value of the camel as a burden bearer, 10–132, 134

Other animals which carry our loads for us, 10-132-34

Things to Think About

Where are men still used as beasts of burden?

Which animals enjoy the snow and cold of the Arctic regions?

How did camels help in the building of the Australian railroad across Australia?

How are goods carried through the jungle to the steamers on the Congo River?

Related Material

Where is the home of the wild donkey? 4-349, 509

What do ox carts look like? 10-143-44

Why were horses important for civilization? 5–87

Why are Shetland ponies loved all over the world? 4-350, 6–486

How is the camel able to help man to conquer desert wastes? 5-395, 444

How does our loyal friend, the dog, help us? 4–492, 498, 501

Leisure-time Activities

PROJECT NO. 1: Make a travois for your dog to pull along, 10-128-29

PROJECT NO. 2: Make a model of a sedan chair, 10–132

Summary Statement

The horse, the ox, and the mule, the elephant and the llama still bear our burdens, and so does man's old friend the dog. They were doing so long before history began.

It would seem to be moving day for these Blackfoot Indians. So they have bundled their worldly goods into a skin or two which they then fasten to a travois for the creatures to drag.

Photo by American Museum of Natural History

PRIMITIVE LAND TRANSPORT

When There Was No Way to Travel Except on Our Own Feet or on Those of Beasts That We Had Tamed

"YOU can no more do that than fly!" cried a father to his boy.

And strangely enough, at the very moment an airplane was flying over their heads, high above the city street. Yet neither of them even looked up. The sight had grown too common!

Now the fact that people still use the father's phrase shows how lately man has taken to wings; and in the long history of our race, speed of any kind is just as much of a novelty. Wise men say that it is about 300,000 years since man appeared on the earth, but all our machines for hurrying about—steamboat, railway, automobile, airplane—have come in the last century and a half. If the long upward journey of our kind should be compared for length to a day of twenty-four hours, it would be only for about the last half minute that we have been dashing about on steamboats and railway trains. Not a very long ride!

You see, man was not made by nature for a speeding animal. Any number of fleet little four-footed beasts can beat him at that game. Just try a race with a deer or a fox, a hare or a whippet! Man's clumsy legs are slow in getting him over the ground; and the birds of the air and the fish of the sea could have laughed at him often.

But though he started with a handicap, man had one great advantage over his little friends of forest and field and stream. It did not lie in the fact that he could carry things in his arms and upon his back, though that was a good deal better than always carrying them in his mouth, like a squirrel or a mother cat. It lay only in his busy, contriving, imagining brain.

For during all the centuries since he began, man has been traveling on his brain! Ever since the early days when he had only his own two legs to move on and his own two arms to carry with, he has constantly been helping himself along with his brain, until now he can fly from New York to London in only a few hours, and can carry half a million times his own weight around the world by land and sea. What a story lies in between!

Man Begins to Carry Things

We have no notion who thought up the earliest means of carrying things from place to place. Probably many men worked out their own notions. But ever since they started, man has been pushing and prying and nosing about the globe, each year growing richer in things and in ideas. Century by century he has come to own more of the world—that is, he has made himself able

to use more of it. He has bored into the mountains and taken away their treasured minerals, he has reached out here for sugar, there for rubber, and everywhere for every sort of thing to meet his need and aid his progress. And he has learned better and better ways to carry all these things home. Up through the ages he has traveled and carried on his brain. He is still doing it.

At first he was occupied with the mere struggle for food. He hunted other animals and was hunted by them. Many of them were far more swift and powerful than he. But his brain hinted to him that he might carry a club both to defend himself and to make his killings. Except for the food he may have brought to his helpless babies, his club may well have been the first thing he ever carried. It was the beginning of transportation.

Then, when man discovered fire, far back in the dim past, he found out, no doubt by some lucky accident, that fire would cook his food That made his food taste better and keep longer. So after a time, instead of eating his fill wherever he happened to fell his prey, he must have got into the habit of carrying his kill all the way back to be cooked at the fire in his cave. As time went on, he gradually found himself moving about more and more, and carrying more and more things. At this stage, the woman was probably the principal burden bearer. She would naturally carry the babies and whatever else she could, so as to leave her mate free to defend the family and pursue game.


Photo by Field Museum

This was man's first method of transport and much the safest way for such a precious possession.

The First Beasts of Burden

Then some resourceful forefather of ours began to tame the animals. Perhaps this may have started by his taking to his cave the young kids or cubs or lambs of some beast he had killed. And as these young creatures grew up around the cave, played with by the children and cared for by the family, they became dependent on their human friends for food and kindness, and each generation grew less and less wild.

Man soon learned that his sheep and goats could be useful to him for flesh and milk and clothing. So he began to keep flocks of them, which he had to move about from place to place in search of grass. As for those playful wolf cubs—when they grew tamer he found they could help to guard the flock. By this time moving about meant transporting more things than the women of the family could carry So man began to put burdens on the backs of his wolf dogs or taught them to drag things over the ground. In this way some of the North American Indians, before the Spaniards brought them horses, hitched dogs to a travois (trà-voi'), a kind of drag which some of them still use with their ponies. When they moved, they dumped their possessions into a skin and bound them to the two tent poles. One end of each pole was fastened to the dog's back and the other ends dragged along the ground.

Dogs may well have been the first of all the animals to be taken into the family. No one knows. At any rate, long before man began to keep any written record of what he did, dogs and horses and donkeys and oxen and elephants and camels were helping him to conquer the earth. Man was using many more legs to get himself and his goods overland than the two that nature had given him

To this day, with all our whizzing trains and automobiles, our speeding boats and

planes, we can still find people in the world who ship their goods on human legs. The Australian blackfellow, setting up camp wherever the food and water are good, carries his throwing stick and his boomerang, while his wife carries the baby and whatever household gear they may own. In some of the roadless hill country of the Philippines and in parts of China, where man power is cheap and the roads are nothing but tracks, the traveler still rides in a chair swung from two poles whose ends rest on the backs of men.

When there is a famine in an out-of-the-way corner of China, people would not have to die of hunger if only there were some way of bringing them food quickly from places where there is plenty. But a man can carry only 133 pounds of rice on his back if he is to average ten miles a day. So you can see that if rice has to be brought very far by a man who must carry along his own food for the trip, it is hopeless to try to save the people by carrying food in this way.

In Korea a man can carry an enormous load on a jigger. It is made of two strong pieces of wood joined together at one end to form the sides of a letter A, and is barred with strong crosspieces. The burden is bound to this frame, which has sling pieces at each side for the bearer's arms. In the Congo thousands of black men walk the jungle paths, carrying on their heads great loads of rubber and ivory and palm oil and copper to steamers on the Congo River or to ships waiting for cargoes on the coast.

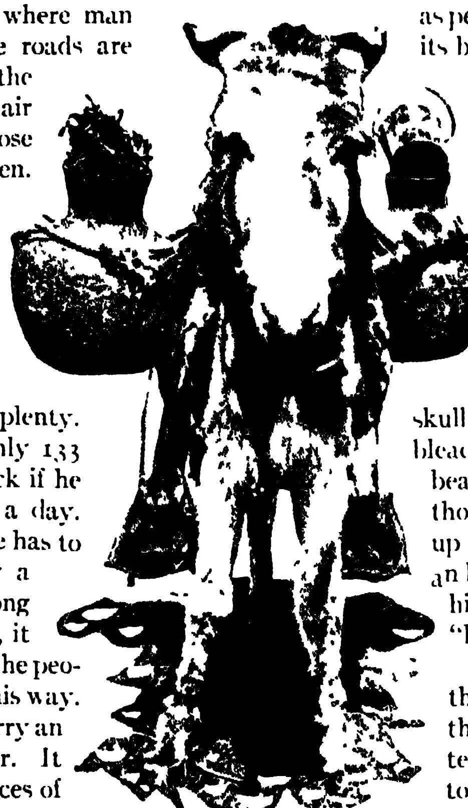


Photo by American Museum of Natural History

There is something about the little donkey that everybody loves he is so sturdy, so comical, and so independent. For thousands of years he has carried man's burdens patiently in many parts of the world, and many a tale has been told to show his humble wisdom.

If You Had Lived in Old London

There have even been times in the past when transport on human legs was the height of fashion—provided, of course, that those legs did not belong to the man who was being carried! At first people laughed and sneered when a haughty duke was borne through the London streets in a sedan (sē-dăn′). It seemed inhuman to use men as beasts of burden. But before long the sedan chair, both private and for hire, had popped up over all the city; and we always think of the eighteenth century belle as peeping coquettishly out from its becoming shadows.

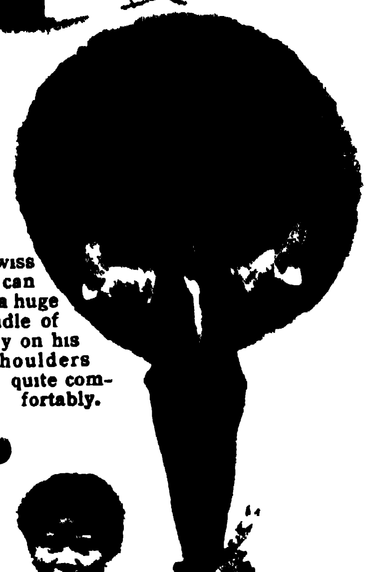
The Eskimos use dogs for their sleds, just as they have done for nobody knows how long. Little Eskimo children, playing with furry husky pups about the igloo, begin training them early by harnessing them to some crude sort of sled or perhaps to the skull of a dead caribou or the bleached shin bones of a polar bear. An Eskimo sled with a thousand-pound load can keep up a steady pace of two miles an hour when drawn by a man, his wife, and two dogs or "huskies."

Not many years ago diphtheria broke out at Nome in the dead of the Alaskan winter, with the nearest antitoxin 650 miles away. For five days and a half the world breathlessly watched the newspapers while relays of huskies, under the direction of brave and skilled drivers, rushed the precious remedy over the wilderness of snow and jagged ice. With the temperature some of the time at sixty degrees below zero, by day and by night without taking time to rest, heedless of bleeding wounds and frozen feet, the relays of dogs covered the ground in half the time it had ever been covered in before, and delivered the serum in time to save the city. Their average was 120 miles a day, and one team did 170 miles without rest. In Central Park, New York, is a statue of Balto, the heroic lead dog who, on the last

In Holland heavy loads are pushed over the ice and snow on sledges like these—and a fine creaking the runners must make on a frosty day It may seem a slow way to get your coal and potatoes home, but it is well to remember that to have all our groceries delivered by motor adds to their cost These people cannot afford it.

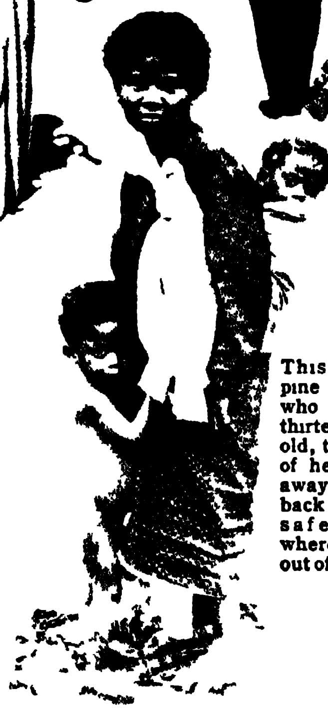
The Chinese coolie carries his load on an arrangement like a pair of scales fastened to a yoke.

Your bread seller at Cairo peddles his strange flat loaves on his head.

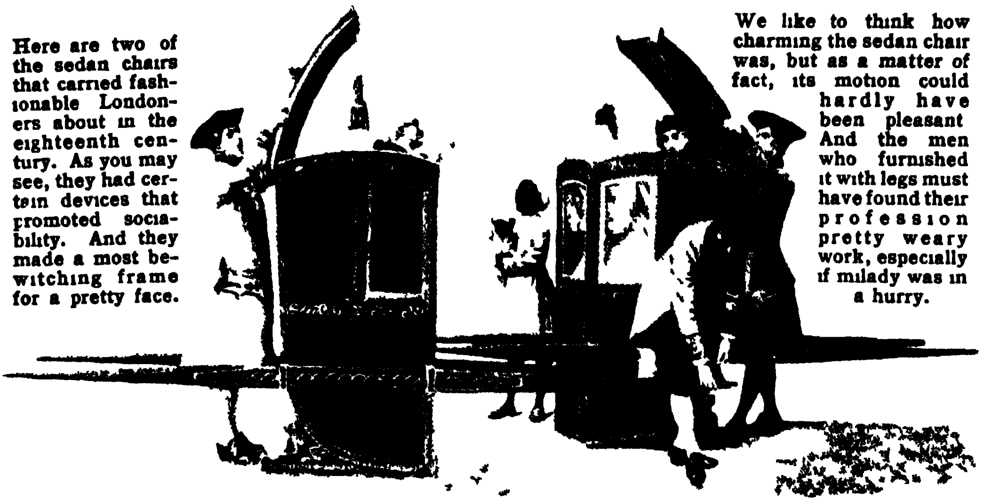


The Swiss farmer can carry a huge bundle of hay on his shoulders quite comfortably.

It must be good sport to ride in one of these Korean conveyances —if one doesn't mind being jolted a bit.

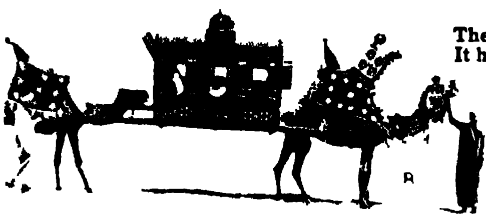


This Philippine mother, who is only thirteen years old, tucks one of her babies away on her back in a good safe place where he is out of the way.



Here are two of the sedan chairs that carried fashionable Londoners about in the eighteenth century. As you may see, they had certain devices that promoted sociability. And they made a most bewitching frame for a pretty face.

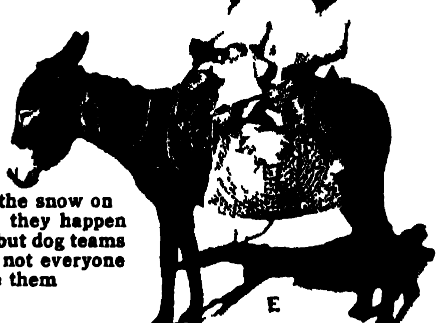
We like to think how charming the sedan chair was, but as a matter of fact, its motion could hardly have been pleasant And the men who furnished it with legs must have found their profession pretty weary work, especially if milady was in a hurry.



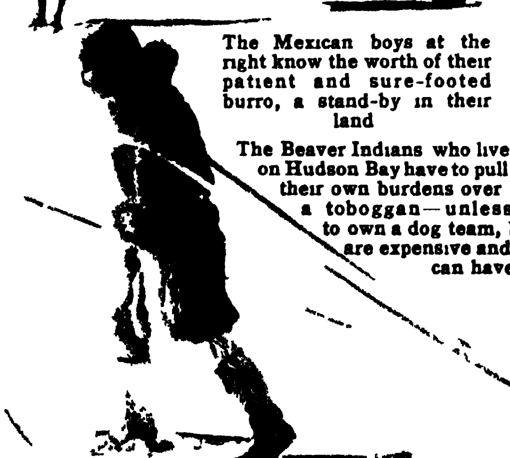
The gorgeous equipage at B is from Cairo It has borrowed a hint from the sedan chair but depends on camels instead of men

At D we may see how bananas are transported on the Canary Islands

Here is still another way of traveling, in South Africa.



The Mexican boys at the right know the worth of their patient and sure-footed burro, a stand-by in their land



The Beaver Indians who live on Hudson Bay have to pull their own burdens over the snow on a toboggan—unless they happen to own a dog team, but dog teams are expensive and not everyone can have them

Above is the only express train of the men of the north, but how swift it is! The sturdy dogs can brave the fiercest weather, and can take their driver home when he is completely lost. The lead dog must possess remarkable qualities of captainship, and be able to trounce any dog in the team.

In Norway the horses are hitched to sledges like this one, and jolly sport it is to speed behind them over the crisp snow.

The dignified ox at the left condescends to transport the people of Nigeria

The elephant is said to have a delightful swinging gait, and serves as a steed in India

The mail truck in Switzerland often goes about on four legs, and weary those legs must get a Christmas time

The reindeer is not afraid of the coldest weather.

Photo by Maryland Historical Society

This pretty sedan chair was used in Maryland in 1750. Those were leisurely days, when no one ever rushed from one engagement to another, and ladies found a sedan much more comfortable than horseback.

lap of the journey, led the way through a blizzard so thick that his master could never have found his path if he had not simply trusted his noble dog's sure instinct.

In Alaska and Siberia the steeds of Santa Claus are faithful servants to man, but the reindeer of Lapland are best of all. There a good team can go at the rate of ten miles an hour, and a good reindeer can cover 150 miles in a day when the snow is hard and the temperature is thirty or forty degrees below zero. He does not have to carry his own food, either, for he can dig down through the snow and nibble the Arctic moss wherever he stops.

Perhaps the oldest trade route in the world is the one the caravans traveled through Palestine down into Egypt. Teas and silks and perfumes from China, India, and Japan, carpets from Persia, coffee from the coast of Arabia, Moroccan velvets and Russian hides, all came over the desert on the backs of patient camels to the merchants of Mecca and Baghdad. And still the long caravans, like gigantic serpents, cover the same hot road. Automobiles and railroads are fast replacing them, but the untiring camel, able to go for several days on his stored-up supply of water, can cover the yielding sand from oasis to oasis at fifty miles a day, and bear the brunt of heavy construction work in thirsty places. The coast to coast railway in Australia could probably never have been laid if camels had not been used to transport supplies and materials. A camel can carry the load of three horses on his back, and has more endurance than any other transport animal.

We Found Something Better Than Legs

The horse, the ox, and the mule, the elephant and the llama still bear the burdens of man. But thousands of years ago man began to ease the load of all his lowly servants when some superb genius gave us one of the greatest inventions of all time. His name is lost to us, but his work lives on, for he changed the whole of human life. He is the man who invented the wheel; and no one since has invented anything that is more important.

TRANSPORTATION

Reading Unit No. 2

PRIMITIVE WATER TRANSPORT

Note: For basic information not found on this page, consult the general Index, Vol. 15.

For statistical and current facts, consult the Richards Year Book Index.

Interesting Facts Explained

How early man rode down a river astride a log, 10–136
Lashing logs together to make rafts, 10–136-37
The first real boats, 10–137-38
The Indians and their birch-bark canoes, 10–138
How the Eskimos made their kayaks, 10–139
When canoes gave way to sails 10–139-40
When early man learned to steer his craft, 10–140

Picture Hunt

Where are oddly shaped canoes used? 10–138, 140
What makes the Eskimo's kayak very light? 10–139

Related Material

How is a canoe paddled? 14–500-11
How long have the South American Indians been building reed boats? 5–499
How do Eskimos fish? 1–199, 9–362
Where are basketwork boats used? 12–130, 134
Why are racing boats called "shells"? 14–532
What kind of boats did the Phoenicians use on the Mediterranean? 5–110
What kinds of boats are used on the Euphrates? 5–90, 94
How are great logs from the forests taken to the mill? 9–249, 251

Practical Applications

How are canoes and boats kept on a true course? 10–140
How are boats made from materials that are close at hand? 10–136-40

Leisure-time Activities

PROJECT NO. 1: Make a model of a "balsa," 10–136
PROJECT NO. 2: Carve out a model of an ancient Egyptian boat, 10–140

Summary Statement

Man's first water conveyance was doubtless a log or branch, but after a time the log was hollowed out to make a boat, and rafts, canoes, and other craft were invented. When they had been skillfully shaped and given poles or paddles and a rudder, man was able to navigate the rivers and lakes of the world.

This was the best the Miwok Indian of California could do when it came to making a boat. He bound together any kind of light wood into a raft, or "balsa," and sent it along with a paddle.

Photo by American Museum of Natural History

PRIMITIVE WATER TRANSPORT

How We Learned to Ride the Water on the Poles and Dugouts That Were the First Parents of the Ocean Greyhounds of To-day

HAVE you ever watched an ocean liner come into port, breasting her way in majesty up the harbor and looming huger and huger until at last she towered like an ocean palace at her pier and set down passengers enough to fill a whole town? "What a wonderful invention!" you may have heard someone exclaim.

But there would be no lordly liners now if some rude genius thousands of years ago had not found out how to beat the baffling rivers by riding them on a log, and later in a dugout. For the log and dugout were the first parents of all the ships that sail, though many a century of marvelous invention was needed to transform the log into a liner.

Before the day of that rude genius a man who came to a river, or a lake or ocean, had no sort of way to get across except by swimming. On the land he could go almost anywhere he pleased, though only very slowly, but on the water he could hardly move at all. But once in a while some man who was swept down a flooded river would grab at a log in the stream and so be carried safe to land somewhere below. Others would learn of the escape, and would know how to save themselves when they were caught in a flood—at least if there was any log convenient. And when the genius came along he showed his brilliance by grabbing at a log, or even launching one, without waiting for a flood at all—simply because he wanted to go downstream. On that day he became the father of all water transport. How glorious he must have felt to be riding down the pulsing river astride his new invention!

And that is about as far as some of the people in the world to-day have ever gone. Every hut owner in certain tribes about Lake Chad in Central Africa has one or two floats made of a certain wood that grows there. It is five times lighter than cork. The floats are shaped like a fish, curving up at one end and tapering toward a point at the other. The men and women throw themselves on these floats and swim off in the water almost as fast as they can run on land.

After a while another genius found out that several logs lashed together would do much better than just one by itself. So he started making rafts on which a whole family might ride. He also learned how to

Model by Ne [illegible] Museum of the City of New York

The first New Yorkers made their boats like this one It was just a tree trunk cut in two and hollowed out to make a craft a good deal like a rowboat. Those little skiffs once swarmed on the Hudson.

push and guide his raft with a long pole To this day the explorers who go far up toward the headwaters of the Amazon employ the rafts of light balsa wood which the Indians there have known how to make for nobody knows how long. Some of the Indians in the tropics make their rafts of four or five banana stems held together with rods of bamboo.

The First Real Boat

In the valleys of the Tigris and Euphrates they still have a clever trick that was invented thousands of years ago. Rafts made of timber and loaded with corn and dates and sesame seed are poled down the rivers to market buoyed up by the skins of sheep and goats filled with air. When they come to the market, the owner sells both the timber in his raft and the cargo on it; then he lets the air out of the skins and trudges home with them on his back.

But if man had gone only as far as inventing rafts, we should never have had our ships to sail the seven seas. He thought out another way of making his log useful to him in the water. Perhaps a hollow tree floating downstream and riding high in the water may have given him the idea. At any rate, he soon learned that if he hollowed out his log it would be lighter and would carry more. Thus he made his first dugout—which we may as well call his first boat.

It was a tremendous job to make the thing. Sometimes he would start with a log that he found already fallen in the woods, but finally he and the men of his tribe came to the point where they would pick out a fine tall tree in the forest and cut it down with their stone axes, aided perhaps by fire. Next they would trim off the branches and cut off the top, still with the stone implements which were all they had. Then they would smooth the sides and shape the round trunk roughly into the form of a fish, which, they had discovered, would make it move more easily through the water. More weeks and months must be spent in digging out the center. First a row of fires would be lighted along the trunk. Then with sharpened stones or shells the boat builders would go at the task of gouging and scraping.

Next the hollow place might be filled with water heated by dropping red-hot stones into it and widened by forcing in cross pieces while the wood was steaming hot. The finest dugouts on the North American continent were made in just this way by the Indians of the Northwest. Some of the dugouts were sixty-five feet long and eight feet wide and could carry as much as five tons. They were made from yellow cedar.

In some parts of the world the men of old built boats of bark or skins stretched over light, strong frames. The Eskimos used driftwood or the ribs of whales for the frame of their kayaks (kī'ăk), and covered them with seal or walrus skin. They carried the skins right over the tops, just leaving one or two holes for a man to slip into. Then, in waterproof coats made of seal intestines sewed together, they kept as dry as could be and wielded their paddles deftly as they skimmed over the water. In the Arctic you will find boats like that to this day—side by side with the motor boats of some of the Eskimos who have made money in furs.

Photo by American Museum of Natural History

People are rarely in a hurry along the Tigris River in modern Irak, so they sail about in a bowl But though a "goofa" may not be the thing to win a boat race in, it must be pretty hard to tip over.

Best of all the boats made by the Indians that our ancestors found in America were the birch-bark canoes built by many of the northern tribes. The canoe builder would pick out a good birch and cut around the bark at the height of his head. He would cut down the length of the section he had made and then, with the greatest care, would peel the bark from the tree. With the tough, pliant roots of the balsam and the larch he would stitch the bark together in the shape he needed to cover the frame of spruce he had already made. Then, after it was all covered, he would make every seam waterproof with pitch.

In such canoes the first white men in America did much of their traveling, for the water courses were commonly the best paths they could find in the dense and pathless wilderness of the New World.

Canoes thus play a big part in the story of the Hudson's Bay Company, that band of "Gentlemen Adventurers of England trading into Hudson's Bay," as they were called in their charter from King Charles II in 1670. The king was so grateful for the help of these gentlemen in putting him back on the throne where his father had lost his head that he gave them the right to about three-fourths of the North American continent.

Now the "Gentlemen Adventurers" were after money, and money was to be made in Canada in furs. So these "lords of the wintry lakes and forests of the Canadas" organized a great business for their time, and one that still goes on under the same name. Beaver skins were their quest, and in the search for the rich prizes they pushed their canoes up the Saskatchewan and over the Rockies and down the Columbia. The bells of their dog teams rang over the snowy stretches of Athabasca, across the Barren Lands, and north to the Arctic. Their horse brigades of a hundred or more adventurers went south over the mountains from New Caledonia through territory that is now Washington and Oregon and Idaho, across the deserts of Utah and Nevada, and even down to the Spanish forts in California.

But canoes handled most of their enormous trade. The furs bought from the Indian trappers were gathered at the Company's warehouses in the big stockaded forts here and there in the vast region they worked. The fur-laden canoes came down the Saskatchewan, which, by many portages and lakes, is connected with the great water systems of the North, and went on to Lake Winnipeg. Then, with many a long portage, they were paddled across to the big warehouse at York Factory on Hudson's Bay, where the furs were loaded on the ships waiting to take them to the Company's warehouses in London.

After a time the Northwest Company, composed mostly of Scotch merchants of Montreal, gave the "Gentlemen Adventurers" a great deal of competition in the fur trade. Their canoes and dog sleds went briskly about in territory the Hudson's Bay people had not touched and built up a huge business that began to cut the profits of the "Adventurers." In the end, after years of trade war, the two companies were merged. At first the canoe men of the Northwest Company were Indians or Highland Scots Later they were of mixed blood from the French settlements of lower Canada. They were bold and hardy fellows, known as "voyageurs" (vwä'yä'-zhûr'), or boatmen, and "coureurs de bois" (kōō'rûr' dē bwä), or woodsmen, who went on long trips that kept them out for months. Through the winter they hunted furs and lived on dried buffalo meat and the game they could bring down in the forest.

The Northwest Company had its headquarters at Fort William up on Thunder Bay in Lake Superior. Every summer the merchants and the fur collectors would meet there. Down on the Ottawa the Montrealers would assemble their canoes. There would be ninety to a hundred of the boats, with eight men in each one. The voyageurs, dressed in buckskins, with bright silk scarfs and headbands, their paddles poised, would wait for the signal of the head steersman. Then down would flash every paddle as one, and the boats were off for weeks of travel to Fort William. The freight canoes, ninety feet long and loaded with four tons each of merchandise and provisions, would drop behind. Like arrows the smaller canoes of the company chiefs would shoot ahead. The merchant would sit at ease in his canoe, dressed in cocked hat and silk-lined cape, with bright buckles on his knee breeches and lace ruffles at his throat and wrists. Now and then he would roll up his fine sleeve and trail an arm over the side. If the ripple did not run up to his elbow, he would shout, "Up-up, my men! Up-up!" The paddles would flash even faster and the voyageurs would break into one of the old French songs they loved so well

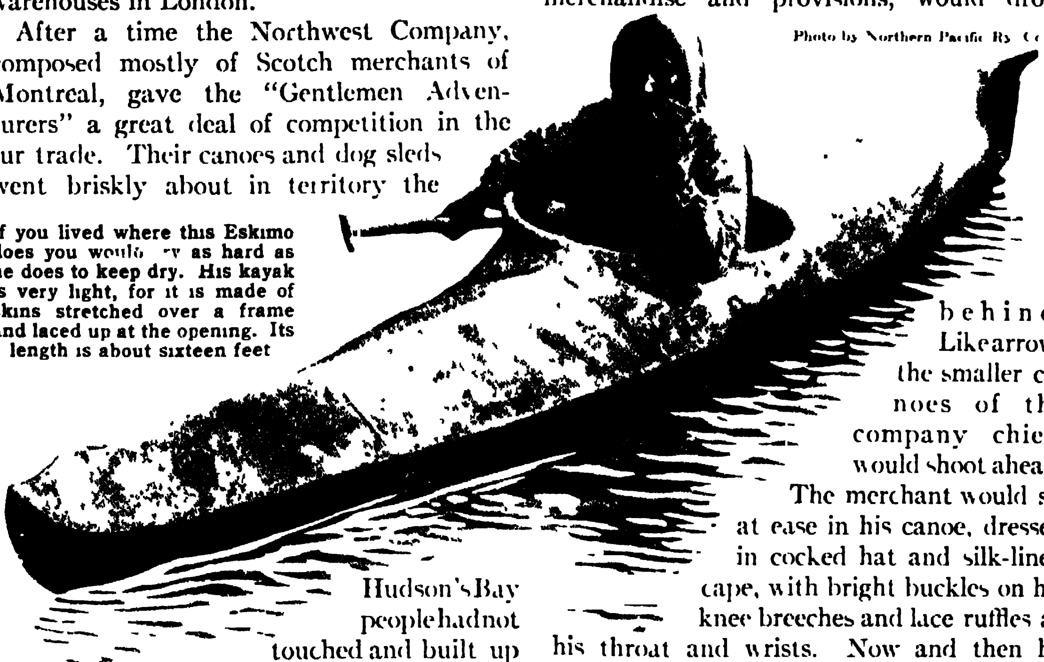


Photo by Northern Pacific Ry. Co.

If you lived where this Eskimo does you would try as hard as he does to keep dry. His kayak is very light, for it is made of skins stretched over a frame and laced up at the opening. Its length is about sixteen feet

When Canoes Gave Way to Sails

Meantime, the fur brigades were coming in from the West, loaded to the water line with pelts. When the two fleets met at Fort William there were days of merrymaking as well as of business, while the furs from the wilderness were exchanged for the muzzle-loading guns, ammunition, brass

Above: Model of fishing and fowling boat, from an Egyptian tomb.

Above: This strange split dugout is used as a ferry-boat in Ceylon. Right: Twenty-four centuries ago people used skin boats like this one from India.

Above: Native canoe in the Philippines. The outriggers, or projecting framework, steady the craft.

ke'tles, knives, hatchets, tobacco, mirrors, bright red flannel, and other goods brought on from Montreal. By August the merchants would turn homeward with their rich booty, while the fur brigades would scatter out through the West for more months of trapping in the cold.

But while dugouts and canoes might be very wonderful in their own way, they could not serve all the desires even of very early man. The winds that swept over the big bodies of water defeated his rowing and paddling and upset his craft when he ventured too far from shore. So he made boats with flatter bottoms than canoes or dugouts; and when he had learned how to make tools out of bronze with a better cutting edge, he built larger water craft of planks that overlapped one another and were held tight with pegs. In the South Seas he built an outrigger for one side of his canoe, or threw a platform across to join two boats. Both these devices helped to steady his craft. Then he found he could put something in his boat for the wind to blow against and help him along. His first sail may have been a tree branch or a skin or mat or blanket held up to catch the wind. But he needed a support for this, and so he thought up some sort of spar or mast. He learned also that he did not have to sail with the wind, but could actually go against it if he wished. He had already found out how to steer his craft with a rudder, an art that anyone will understand who has ever trailed an oar from a boat. Even before that he had fallen into the habit of noticing the stars and had found out which ones might be relied upon to keep him on a true course.

And now, with the wind to push, a rudder to guide, and stars to steer by, he was "all set" to range the deep!

He had reached this point long before the dawn of history. And to-day there are peoples in the South Seas who have never passed this point, but have stopped still while the rest of us have gone on to ocean liners.

TRANSPORTATION

Reading Unit
No. 3

AS SOON AS WE HAD WHEELS

Note: For basic information not found on this page, consult the general Index, Vol. 15.

For statistical and current facts, consult the Richards Year Book Index.

Interesting Facts Explained

People who knew nothing of wheels, 10 143
The crude beginning of the wheelbarrow, 10 143
Early war chariots with spoked wheels and with axles and rims of metal, 10 144
America's first stagecoaches, 10 146
When the first good roads were built, 10–146
The first four-wheeled vehicle to cross the Rockies, 10 148
Turning the Wilderness Trail into a road, 10 148
When fleets of wagons with jingling bells went by, 10–148

Things to Think About

Why did it cost $100 to get a ton of freight from Buffalo to New York in 1817?
What put the old Conestoga freight wagon out of business?
Why did men travel on horseback in the Middle Ages?
What improvements were made in the wheels of ancient Egyptian war chariots?

Related Material

How does a blacksmith remove an iron rim from a wooden wheel without breaking the wood? 1 479-80
How does the wheel-and-axle principle work? 1 330-31
How did people travel across the western prairies and the Rockies in the "fabulous forties"? 10 -153, 7-231-32
What was the famous one-horse shay like? 6 384
Why is the horse of greater value to us than donkeys or bullocks? 5–87
In what ways are racehorses different from other horses? 4–511-12, 514
How was coal hauled back and forth in the mines in days gone by? 9–444
How many miles of road are there in the United States now? 10 156

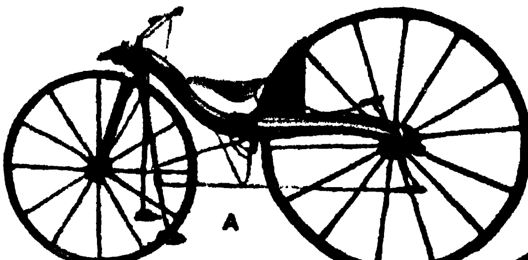
Practical Applications

How did people travel long distances in the days before the railroads? 10 146
How long did it take wagon trains to get from Boston to Baltimore when the National Road was opened? 10 148

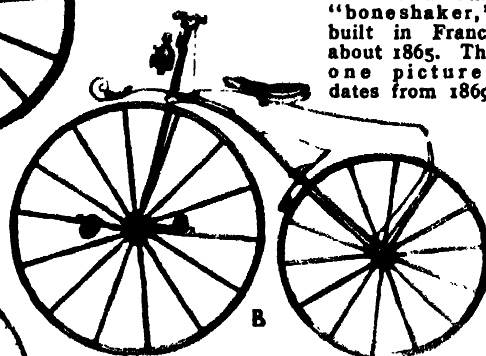
Summary Statement

Our modern civilization runs on wheels, with the result that if we cannot go on wheels we are likely to stay at home.

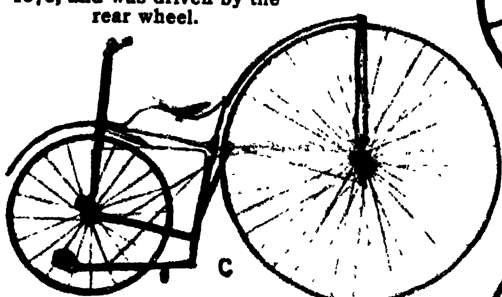
A—In 1839 a Scottish blacksmith named MacMillan built a machine like this one. Before that there had been two-wheeled affairs called hobby horses, propelled by the rider's feet pushing on the ground.



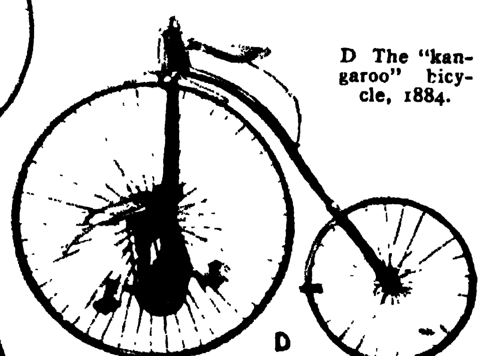
B—Next came the "boneshaker," built in France about 1865. The one pictured dates from 1869.



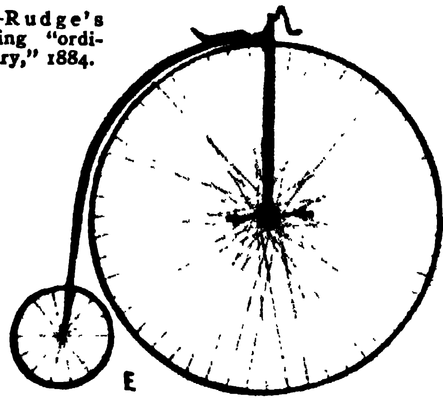
C—Gradually one wheel grew larger, till the so-called "safety" bicycle was developed. This one was built in 1876, and was driven by the rear wheel.



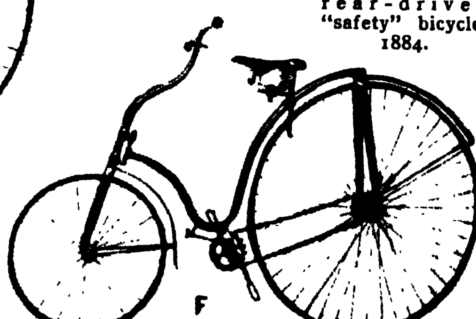
D The "kangaroo" bicycle, 1884.



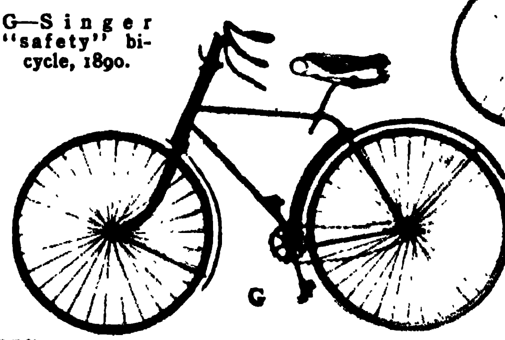
E—Rudge's racing "ordinary," 1884.



F · McCammon's rear-driven "safety" bicycle, 1884.



G—Singer "safety" bicycle, 1890.



H - Above is the history of the bicycle. Way back in Egypt and Babylon the idea had been thought of, but nothing was done with it for many centuries. After the toilsome wooden boneshaker was invented, men gradually added rubber tires, ball bearings, tubular metal frames, the coaster brake, and two more gears.

Photos by Science Museum, London

These Spanish ox carts seem quaint enough to us, but to men of the Stone Age they would seem marvels of invention. It all depends on the point of view. It is only lately, in comparison with the long history of mankind, that we have had wheels at all.

Photo by Spanish Tourist Information Office

As SOON *as* WE HAD WHEELS

Long, Long Ago Some Rude Genius Made One of the Most Important of All Inventions When He Found Out How to Roll Things

JUST suppose that all the wheels in the world were suddenly to stand still—jinrickshas in Japan, passenger wheelbarrows in China, ox carts in Mexico, big bullock wagons creeping over the plains of Australia, little donkey carts in France, and motor trucks and automobiles and railroads! Suppose that not a factory wheel, not a watch or a clock or a turbine were running. Then you will realize how fully our modern civilization runs on wheels. If we could not go on wheels, we could hardly get anywhere at all. We should be back pretty close to savagery.

Yet for centuries on centuries, man had no wheels to go on. He had to invent them. And the invention was one of the most important of all time, for countless other things depended on it. Some races never got as far as the wheel in their discoveries. Our North American Indians knew nothing at all of wheels. Neither did the Eskimos, who, of course, did not happen to need them in their cold lands.

How the invention came about, or when, nobody knows. When the Egyptians began, over five thousand years ago, to write the story of their deeds and to put pictures of scenes from their lives on the walls of their tombs, they already had wheeled vehicles. Possibly the first wheel had long since been invented somewhere in the Nile Valley or over by the Tigris and Euphrates. Perhaps a man one day noticed a rolling log and thought that if he could put rollers like that under some of the heavy things he wanted to move, he could get them over the ground a bit faster than by dragging them. So after a time log rollers came into use.

The Very First Wheel

Then, a great deal later, someone else probably had the bright idea of putting a round section of a log in the joining between the two poles of his travois (trȧ'voi')—or V-shaped drag. It was the crude beginning of a wheelbarrow. Later still some ingenious man must have thought of mounting his sledge on two of those solid disks joined by a pole stuck through holes in their centers.

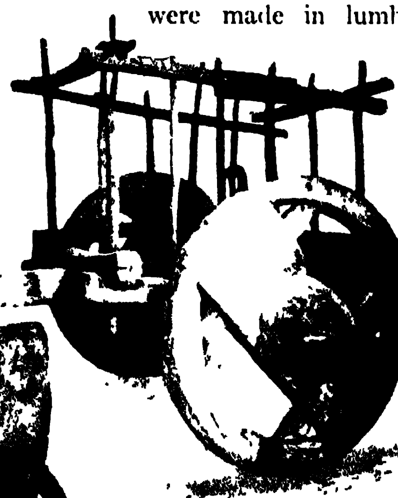
So he made the first two-wheeled cart. And what a difference even that bungling contrivance must have made to the dog or camel or donkey or ox that had to drag the load along the ground! As for the man himself, he doubtless felt as if he were riding on air.

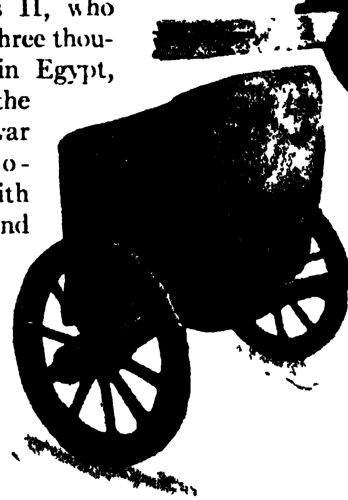
How Axles and Spokes Were Invented

Time went on, and the news of the wonderful invention spread. Men began to think out improvements. After a while metal axles eased things still more for the beasts that pulled the vehicles. Men began to cut small sections out of the solid disks to make them lighter Then the disks gave way to rims of wood banded with metal and strengthened with spokes. On the walls of the tomb of Ramses II, who ruled more than three thousand years ago in Egypt, are pictures of the king's elegant war chariots, two-wheeled affairs with sturdy spokes and with axles and rims of metal. But there are also pictures of some of the king's enemies going forth in war chariots with solid wheels that must have put them at some disadvantage in battle.

Like the Egyptians, the Assyrians and the Persians went to battle in two-wheeled chariots, and those in which the Romans thundered around their arenas had only two wheels. So had the farm carts of ancient Italy, such as the ones that brought wine and olives to the markets of Pompeii before the eruption from Vesuvius stilled its life forever in the year 79 A.D. But four-wheeled vehicles had been invented before that. The body of Alexander the Great, who was conquered at last by death in Babylon in 323 B.C., was taken in its gold coffin on a magnificent four-wheeled funeral carriage to Alexandria in Egypt. Ladies of wealth and position in ancient Rome reclined behind rich curtains in carriages with four wheels, but a man was laughed at if he rode in such womanish style.

On the whole, the world was fairly slow in getting on wheels. For one thing, roads were bad and travel was risky, what with robber barons and footpads. Goods transported for long distances overland went mostly by pack animals, and short hauls were made in lumbering carts and rough wagons, as they are to-day in backward or sparsely settled countries. Through the Middle Ages in Europe men traveled on horseback, often in groups for protection, and women traveled scarcely at all. It was not until about the time that Sir Walter Raleigh set out on his ill-fated attempt to found a colony in Virginia that English gentlemen began to own private carriages Then, just as taxis and motor buses followed private cars, hackney coaches—or coaches for hire—and stagecoaches came after the private equipages. By 1631 the narrow streets of London were so jammed that there were many public complaints about the state of the traffic which read like the complaints in our papers to-day.





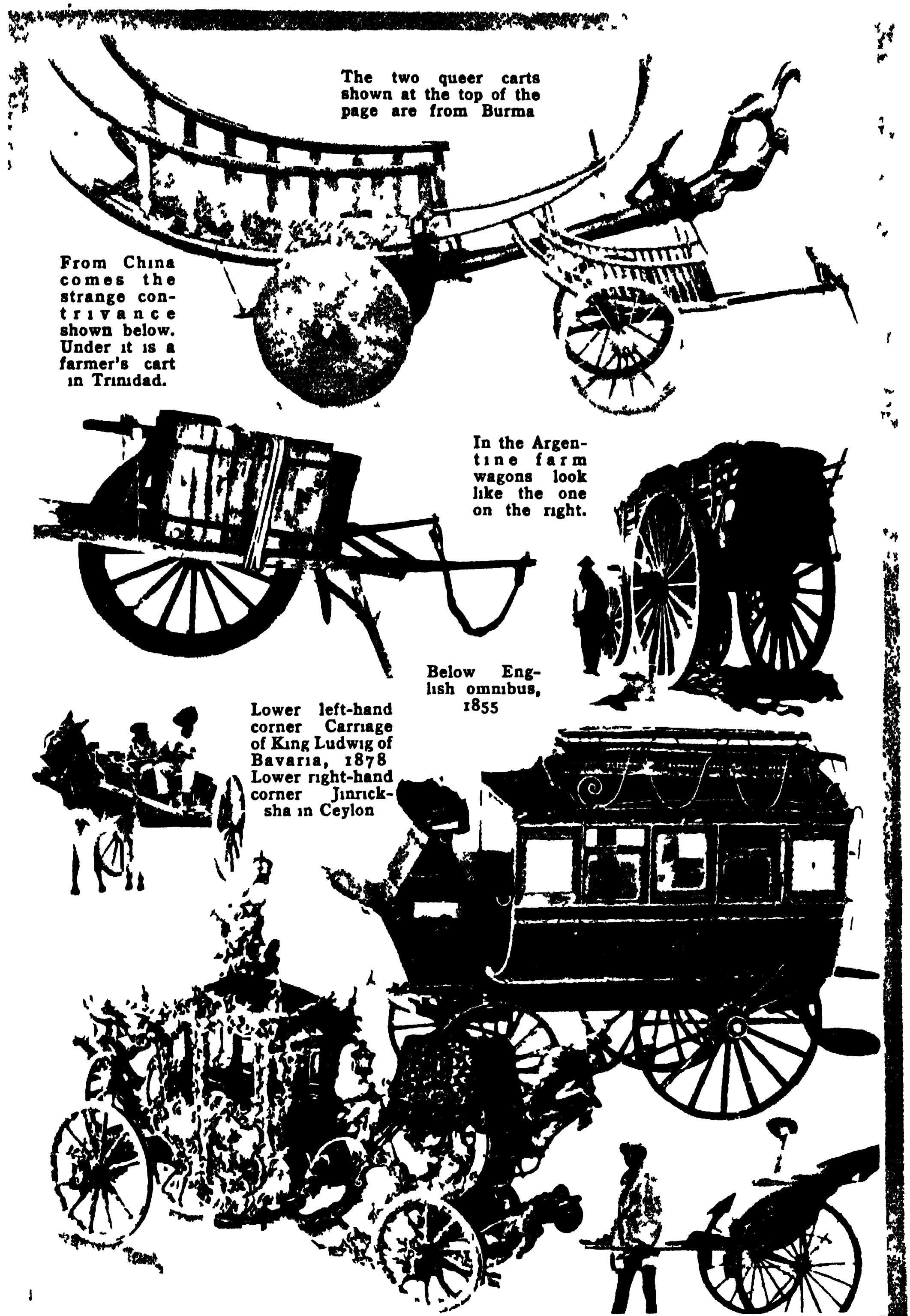
Photos by Alinari and the National Museum

Ox carts like the one at the right are still used in Spain, where time is not so precious as in the New World. The Etruscan chariot at the left, used by a people of Italy long before the birth of Christ, looks quite modern in comparison.

When Wheels Invaded the Land

Stagecoaches began to ply on the roads between the principal English towns. There were laments about the number of ash trees that had to be cut to build all "these great

THE INVENTION OF THE WHEEL



The two queer carts shown at the top of the page are from Burma

From China comes the strange contrivance shown below. Under it is a farmer's cart in Trinidad.

In the Argentine farm wagons look like the one on the right.

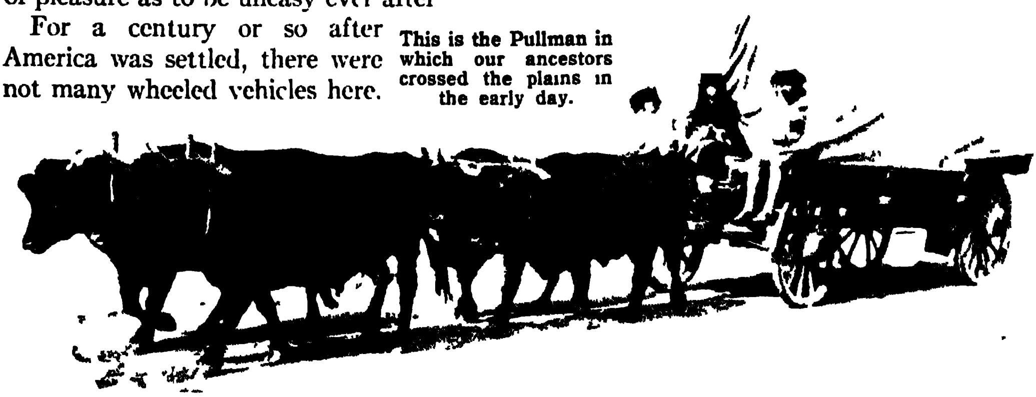
Below English omnibus, 1855

Lower left-hand corner Carriage of King Ludwig of Bavaria, 1878 Lower right-hand corner Jinricksha in Ceylon

Photos by Science Museum London American Museum of Natural History Visual Education Service Field Museum and Rys. of Germany

tortoises on wheels that run about England." One gentleman wrote to the papers saying he was alarmed at the possible effects of this rapid travel. Actually, he wrote, in one of these modern stagecoaches one could get from Dover to London, a distance of nearly sixty miles, in three days. What was England coming to? Men would visit London on the slightest excuse, to get a hair cut or for any such frivolous errand. Their wives would insist on coming with them and would "take occasion to get fine clothes, go to plays and treats, and by these means get such habits of idleness and love of pleasure as to be uneasy ever after"

For a century or so after America was settled, there were not many wheeled vehicles here. They were far from comfortable on such roads as we had, and only the wealthiest persons could afford them. George Washington, one of the richest men in the colonies, did not own a coach at the time of his first inauguration. He set out from Mount Vernon on horseback to become our first president in New York. At Mount Vernon you will see a coach like the one that Washington later bought from Governor Richard Penn of Pennsylvania, who had imported it from England. It was cream-colored with gilt moldings, and it created quite a sensation when the President and his wife and their two grandchildren were driven about the streets of Philadelphia and New York in it behind six spanking bays.



This is the Pullman in which our ancestors crossed the plains in the early day.

Photo by B & O Ry

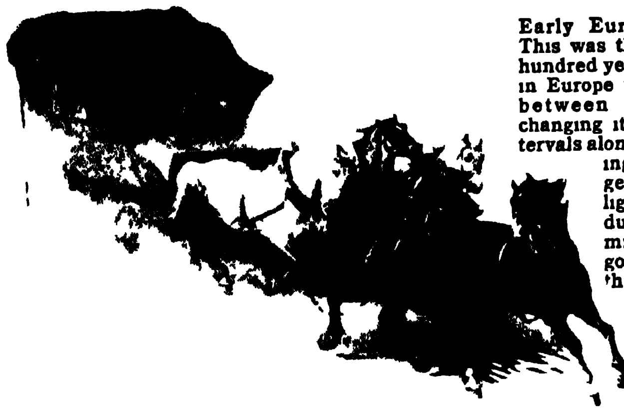
America's First Stagecoach

Thomas Jefferson did not own a coach. When his young bride came up the mountain to the spot where he later built his beautiful home, she was seated behind her husband on a pillion—which is the way that many women traveled in those days.

The first line of stagecoaches in this country ran between Philadelphia and New York. It was opened in 1756 and it took three days to make the trip, which a good train now covers in two hours. When one of the coach owners managed to cut the time to two days, he advertised his coach as the "Flying Machine." At first it took a week to go by stage from Boston to New York, though this was later cut to four days. And what a journey it was! Josiah Quincy, president of Harvard College, wrote a friend that the carriages were old and ramshackle and the harness mostly of ropes If there were no accidents, the passengers reached an inn by ten at night and after a scanty supper went to bed. They were called at 2:30 in the morning and they dressed by a horn lantern with a poor candle. They often had to get out and help push the stage out of mudholes.

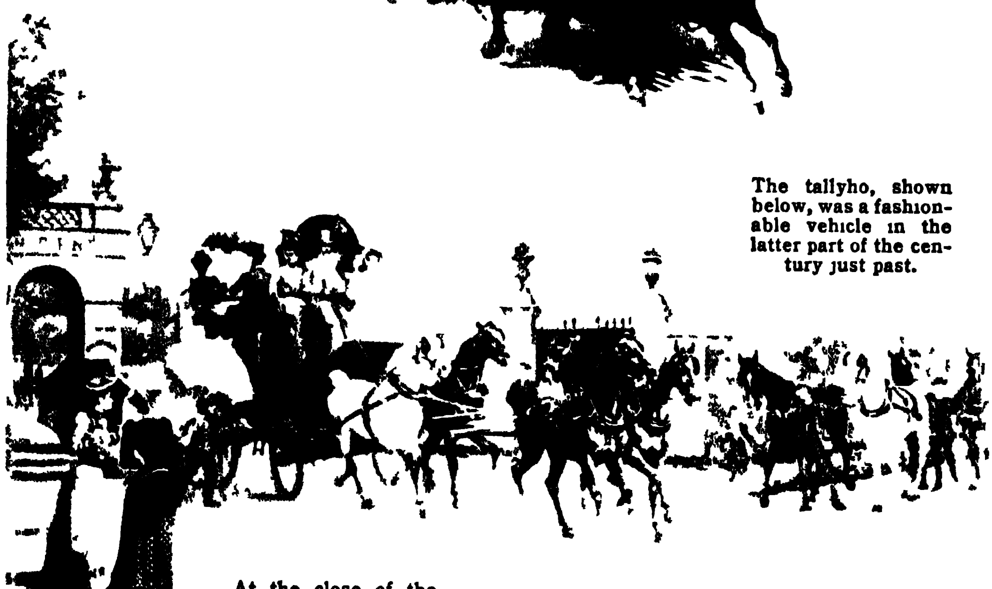
The First Good Roads

Along the roads were taverns for the stagecoach passengers, and road houses for the drivers of the freight wagons and carts that had begun traveling about the country. Not long after Washington became president, the Lancaster Turnpike, sixty-six miles of good hard road to Lancaster, Pennsylvania, was opened. In a short time it was alive with freight wagons, bringing to Philadelphia the produce from the splendid farms about Lancaster and taking back goods bought in the city Iron from the Pennsyl-



Early European stagecoach. This was the Pullman of three hundred years ago. Everywhere in Europe the stagecoach plied between crowded centers, changing its four horses at intervals along the road and carrying its shaken passengers at what seemed lightning speed through dust and mire. Eight miles an hour was a good average for it in the eighteenth century.

The tallyho, shown below, was a fashionable vehicle in the latter part of the century just past.



At the close of the last century fashionable people in England rode in carriages like the ones below.

Photos by Modern Museum Brussels and Gramstorff Bros

vania hills was carried in a special kind of wagon—a big, strong affair with broad wheels and a body that swung down in the middle and curved up at the ends. The under part of the body was always painted bright blue and the upper part bright red. On a framework over the top was a covering of white canvas to protect both the goods and the drivers on the long jaunts. The six horses had fine leather harnesses and wore rows of jingling bells. So began the rôle of the Conestogas (kŏn′ĕs-tō′gȧ), named for the town in Pennsylvania where they were first made, which was itself named for the Conestoga Indians of those parts.

In time those wagons made more than freight history, for it was a Conestoga that Marcus Whitman, by hook and by crook, took over the Rockies when he and Henry Spalding and their wives went as missionaries to the Indians in the Columbia River Valley. That was the first four-wheeled vehicle to get over those mountains. An old fur trapper, looking on, made a true prophecy when he said, "There goes the end of the fur trade. When wheels can cross the Rockies, then the settlers." It was not long before a train of a hundred covered wagons started from the Missouri with settlers and their goods and families on the long, long Oregon Trail to make homes in the unknown West.

Turning a Trail into a Pike

One of the first big undertakings of the infant United States was the building of the National Road. Starting high in the hills at Cumberland, Maryland, it came down through the little raw new capital of Washington on the Potomac and then struck westward to Wheeling along the Wilderness Trail, followed by Daniel Boone and the pioneers that came after him. The road was finished in 1817 and was soon full of traffic of all sorts. From any hilltop one could see whole fleets of white covered Conestogas rolling along, with the noise of the jingling bells drifting back on the wind. The drivers, great strapping fellows, their faces brick-red from being out in all weathers, had many a tale of the road to tell each other when they drew up at the road houses at night. They would attend to their horses, then make a dash for the public room. There they would stow away huge meals, sing songs, swap stories, dance to the tunes of the fiddlers among them, then slip off their boots and lie down on the floor with their feet to the fire to sleep until daylight should send them out on the road again.

Wagon freighting was a well-established business in most of the states by the time the National Road was opened. Wagon trains were making trips from Boston to Baltimore in twenty-six days and from Baltimore to Richmond in ten. But it cost $100 to get a ton of freight from Buffalo to New York; and $100 then was surely as much as $400 now.

Meanwhile a mighty change was on the way. In England George Stephenson, after years of patient toil, had invented the locomotive. From now on wheels were hitched to steam. Good-by to the lumbering stage and the cumbersome Conestoga. Man was to race with the wind and outstrip the birds in flight; he was to pull thousands of tons with a single engine.

Reading Unit No. 4

THE SPEEDWAYS OF THE WORLD

Note: For basic information not found on this page, consult the general Index, Vol. 15.

For statistical and current facts, consult the Richards Year Book Index.

Interesting Facts Explained

When roads were trails through the wilderness, 10 150
The first great roads built by the Romans, 10–150-51
The Appian Way, 10 151
When roads were full of color and jostling life, 10–152
When Telford and McAdam improved roads, 10–152
The Cumberland Road, America's first highway, 10–153
Modern roads and where they go, 10 156

Things to Think About

What led to the decay of the magnificent Roman roads?
What method of road-building did Telford and McAdam introduce?
Why are highways higher in the middle than at the sides?
When were the tables turned on the railroads?

Related Material

How are solid rocks turned into dust and sand? 1-94-95
Why do cracks appear in roads two or three years after they are built? 1 479
What were logging roads like in the old-time logging camps? 9–248
What is reinforced concrete? 11–518
Where did the word "macadamize" come from? 10-20, 152
How much coal tar do we get from a ton of coal? 9–445
What is Pitch Lake in Trinidad filled with? 7–66

Practical Applications

What are the best types of highways for different sorts of traffic? 10–156
How is the movement of traffic on streets and highways controlled? 10–156

Leisure-time Activities

PROJECT NO. 1: Find out how roads are constructed in your town, 10–156

PROJECT NO. 2: Watch men at work on road construction, 10–155

Summary Statement

To-day the parade along the roads of the world is something that no old Roman ever dreamed of, for it carries the teeming life of our Machine Age—an age dependent on its roads.

Photo by Chauffourier Rome

Across the Roman countryside this age-old road still stretches its white length. It is the Appian Way, the first and most famous of the great highways of the world. Along this road, it is said, St. Peter fled from Rome to escape a martyr's death. But he had not gone far before he saw Christ advancing toward him. Awestruck, he said, "Domine, quo vadis?" "Master, where goest thou?" To which Christ answered simply, "I am returning to be crucified again." The apostle was so ashamed of his own cowardice that he turned back to Rome. To-day a little church marks the spot where the meeting is said to have taken place.

The SPEEDWAYS *of the* WORLD

The Men of Old Would Be Almost as Much Amazed by Our Network of Fine Highroads as by the Countless Machines that Whirl over Them

WHAT a pageant of history has passed up and down the roads of the world! For almost from the beginning men have always been going somewhere from somewhere else. If they should suddenly cease doing so there would be an end of civilization. And now as never before, the nations are bound together by their roads.

The first roads were merely trails through the wilderness. Wild creatures make them yet in mountainous or wooded places in the Andes or the Adirondacks--as they go to water or grazing grounds. Savages follow the animal trails or make more of their own. Deep in the jungles of the Amazon, Indians from a certain tribe still go once a year for many miles along such a trail to bring back the year's supply of salt from the nearest trader's house on the great river. As men trained animals to carry or drag things for them, the trails grew wider. When they learned to put wheels under their burdens, the trails grew wider yet. But still they were simply trails, and only by accident roads.

For a road is something planned and built Neither the trails nor the ancient caravan routes across level desert sands from Europe into Egypt, Arabia, and India were really roads. The first great roads we know of were made by the Romans. Built to last, they were so well laid that even after two thousand years and many centuries of neglect there are still many traces of them left. More than that—some of them have even been repaired and are still in use! Wherever the conquering Roman legions went, fine highways were laid down, always going in the straightest possible line between the

Photo by Rischgitz

This quaint picture, called "Stuck Fast," shows the plight of one of the old English stagecoaches on a snowy night. Do not imagine that this sort of thing never happens to-day. Even on a state highway a motorist traveling on a winter's night may encounter a sudden blizzard. His tires will skid and make no progress in the deepening drifts. There is not time to put on chains, and the snowflakes are blinding. There is nothing to do but abandon the car, hunt for the nearest farmhouse, and wait for the snowplow.

points to be reached. And "all roads led to Rome."

The most famous of all the Roman roads was the Appian (ăp'ĭ-ăn) Way, begun more than three hundred years before the birth of Christ. It was fourteen feet wide, and formed of layers of broken stone and lime, broken brick and pottery, and more broken stone, all rammed down on a firm foundation of dry earth and topped off with great paving stones fitted exactly together. There were raised footways on each side. Blocks were set up at intervals to make it easy for horsemen to mount. Milestones marked off the distances. These finally reached from Rome to Brundisium, three hundred and fifty miles away. Two stone pillars on the seacoast marked the road's end there, and on the opposite side of the Adriatic two more pillars showed where the road began again, to cross Greece and go on to Constantinople.

Along the Appian Way

Along the Appian Way marched the pageant of the empire: Roman conquerors, returning home laden with spoils; Greek slaves, who would teach their captors all the arts and learning of their fallen homeland; merchants and messengers and common people, and armies marching and countermarching for the prize of a world. And so was it, in a lesser way, with all the other great Roman roads, some of them as far off as the island of Britain—where the famous "Watling Street," from London to Wroxeter, near Shrewsbury, is still in use to-day. No wonder Augustus, first of the Roman emperors, set up in the Forum a "golden milestone" on which were marked the names of all the roads of the empire.

The Decay of Roman Roads

When, in the fifth and sixth centuries, the empire fell a prey to the barbarians, all these magnificent roads went gradually to ruin. For thirteen hundred years and more the roads of Europe grew worse and worse. Nobody seemed to think it was his business to keep them up. There were no strong national governments; and when the feudal barons rode off to war, they expected to splash through the mud on their doughty steeds. Sometimes the good monks cared for the roads near their monasteries; at one time the order of "Bridge-building Friars" did much good work in keeping both bridges and roads in repair. The hermits lent a hand, too, laboring at road mending to break the monotony of their solitude. But the mud got deeper and deeper and the roadbeds more and more full of bumps. Queen Elizabeth of England, one of the proudest monarchs of her day, would not ride in her new coach through the streets of London because,

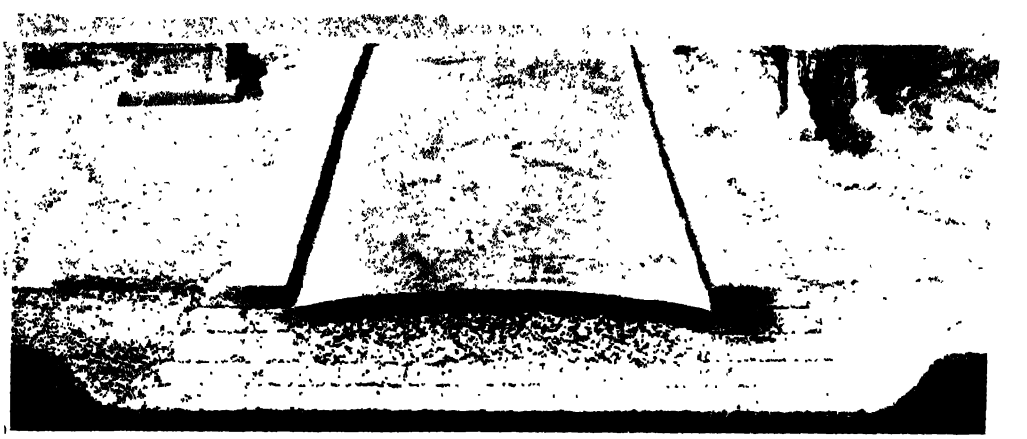


Photo by Deutsche Mu

No wonder so many of the old Roman highways are left! This cross section will show you how such a road was built, with many layers of brick and stone crushed or carefully fitted together to make a foundation almost as resistant as the age-old rocks. The surface was slightly arched so that water would run off.

she said, she would be sore and bruised from head to foot with the jolting and jostling of it. So, like everybody else, she rode a horse.

Such highways as there were between town and town were infested with robbers. No man traveled alone if he could join company with others. Yet all through these centuries the roads, however bad, were full of color and jostling life—merchants and peddlers, jugglers and wandering minstrels, knights on prancing chargers and monks on ambling mares, beggars and pilgrims, runaway peasants and thieves, and princes on their travels. A pageant of history indeed!

During the seventeenth and eighteenth centuries more people were venturing over the roads on wheels. But it was during the seventeenth century that a wagoner in England lost a wagon and six horses in a mudhole on old Watling Street—once a Roman road! Sussex was so famous for its mire that it gave rise to a saying that Sussex men and women got their long legs from pulling them up out of the mud. And even in the eighteenth century a journey by stage to London from a town fifty miles away was an undertaking of daring and danger.

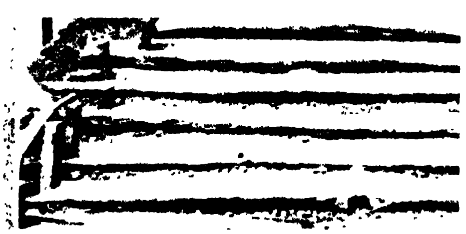


Photo by Deutsches Museum

Here are the remains of an old plank road which was built in 5 B.C. over the swampy moors in what is now Northern Germany. This kind of road is mentioned by Tacitus, the Roman historian. Who knows how many sturdy soldiers marched to victory or how many weary prisoners passed to slavery or death over these same planks, now so time-worn and battered!

Road improvement did not begin in earnest in Europe until, during the first half of the nineteenth century, Telford and McAdam introduced their methods of digging down to a good, dry foundation, and then building up the road with crushed stone. The ideas of these two Britishers, combined and improved to suit special needs, form the basis of all the many excellent highways of Europe and America to-day. Telford's name is almost forgotten, but we recall McAdam every time we speak of a "macadamized" road.

Because their country is so large, the Americans have always had to think a good deal about ways of getting from one part of it to another. At first they followed the Indian trails and the river ways. For a long time, until the Revolution, they did not make much attempt to use wheels. Instead they walked or went on horseback when they had to go overland, or—

Indian trails and narrow paths worn by the wild beasts were the only roads the pioneers found as their caravans passed over the great plains. Yet on they went, through treacherous mud, blistering sands, and tangled forest lands—west! And when they came to rivers the prairie "schooners" became boats indeed.

by preference they traveled by water in ship or canoe. Not until 1792 was there a single really good road in the country. This first good road was the Lancaster Turnpike, which ran from Lancaster, Pennsylvania, to Philadelphia, a distance of sixty miles. The company which built it made a fortune from the tolls they charged, for it became a great freight highway. When Dickens, the novelist, visited the United States in 1842, he still found a ten-mile journey on a stage such a succession of jolts and pitchings and hair-breadth escapes that it seemed to him a miracle when the black driver could promise to "get you through, sa, like a fiddle."

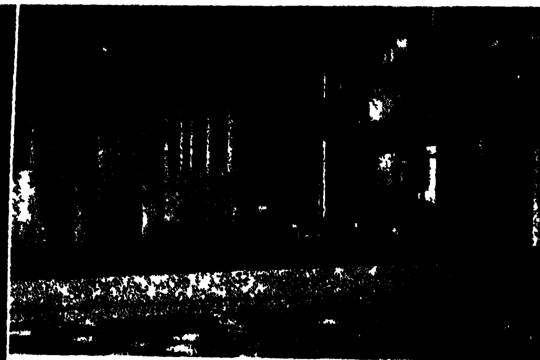
America's First Great Highway

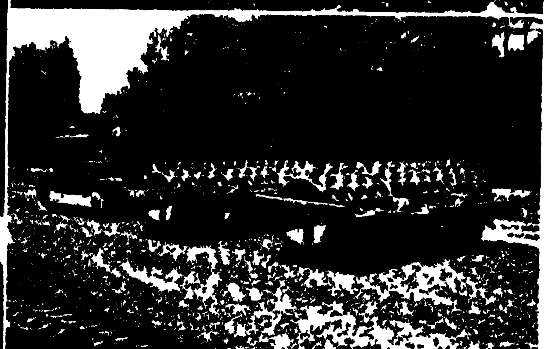
Yet Washington had dreamed of a national highway which should bind the young nation together. And a good many years before the time of Dickens, work had been begun on the Cumberland Road, or National Pike. It started from Cumberland, Maryland, on the Potomac, and was built westward, in sections, as Congress granted money for it. By 1840 it had gone as far as Vandalia, Illinois.

And here was the setting for another pageant, very different from the others. For the life current of the young nation flowed along the Cumberland Road. There were scouts and pioneers in buckskin and homespun. There were riders in handsome carriages and fast stagecoaches. There were politicians traveling toward the straggling little seat of government on the Potomac. There were Conestoga freight wagons rolling along hour after hour. Along the road were inns and road houses, where plentiful portions of mountain trout and venison and corn cakes might be eaten to the accompaniment of many a "tall" tale of the road. Presidents Jackson, Van Buren, Harrison, Polk, and Tyler all traveled the Cumberland Road to their inaugurations.

The Age of Great Highways

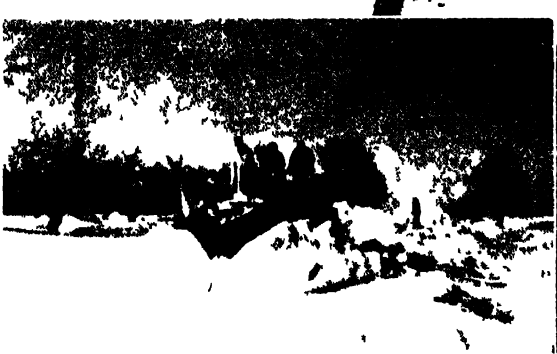
But, after all, the day of the highways had not yet come in America. In the middle of the nineteenth century everyone was building railroads, and one could now get from East to West much faster on a railroad than in a lumbering stagecoach. Not until the beginning of the twentieth century did the





Photos courtesy New York Department of Parks and NYSPIX DPW

The line of a curve, the design of an intersection mark the difference between life and death on our crowded modern highways The swift stream of traffic gives a driver no time to stop and think and no chance to change his mind, once he has gone wrong So engineers spend their best talents working out the currents of traffic for a complicated intersection like the one above, which you will be interested to puzzle out Highways of this kind are always made of reinforced concrete First the soil is carefully tested to learn its properties under every sort of condition At the top above is the machine that tests its behavior under freezing and thawing Just below it you see the foundation of the roadbed as it is leveled with steam shovels. Sheepsfoot rollers third from the top break up the lumps and work the surface till it is ready to receive the mixture of rocks, gravel, and concrete that make up the road. This mixture is



Photos courtesy U. S. Public Roads Administration and NYSPIX-DPW

combined in the great power-driven machine shown in the bottom picture. The machine has long arms that reach across the roadbed to level and grade it. They rest on wheels running on planklike "forms" set up along each side of the road to serve as a track and also to hold the concrete mixture. At the top right the concrete is being poured. The machine levels it with a back-and-forth motion that makes the rocks and gravel sink toward the bottom. The steel reinforcement is than let down into the concrete—as shown in the next picture. Now the road is given the smooth surface or "finish"- of the third picture. After it hardens it will stand all weathers—as our snow plow at the bottom is finding out. The highway at the right has been planned for safety. Note the grassy strip down its center.

railroads find the tables turned on them. Then automobiles began to swarm like locusts and the roads had their revenge.

In 1891 New Jersey passed the first law giving state aid to counties in the building of roads. Other states were soon following New Jersey's example. By 1916 the federal government was helping the states to finance and build roads for interstate traffic. Since that time the federal government has helped the states more and more in their road building. Highway officials in all the states work together to help give the nation a system of good roads to meet the needs of modern travel.

There are several million miles of road in the United States now, enough to go around the earth more than a hundred times. Not all of these are of the best as yet, but thousands of miles of them are. All the chief cities of the nation are linked together. Then there are the transcontinental highways, such as the Lincoln Highway from New York through Philadelphia and Pittsburgh to San Francisco, and the National Old Trails over the three thousand miles between Washington and Los Angeles. These great roads are protected by danger warnings at every curve and railroad crossing, and marked off with mileposts bearing the shield of the United States.

The Pennsylvania Turnpike, between Harrisburg and Pittsburgh, was the first of a new kind of express highway. On it everything possible is done to insure safety and speed. The road by-passes cities and towns, has no dangerous curves or crossings, and because it tunnels through the mountains has only the gentlest grades. All vehicles using it must pay a toll. It has served so well that other states—notably New York—have planned similar highways. By the the close of World War II Congress had plans for 1,200 miles of super highway to link various busy regions.

During the war the Army in nine months built the Alcan—or Alaska-Canada—Highway to carry supplies through the untamed wilderness between Dawson Creek—near Edmonton, Alberta—and Fairbanks, Alaska.

Road engineers have studied the best types of highways for different sorts of traffic. Sand-clay, gravel, and waterbound macadam will do for light traffic. Waterbound macadam is made of two layers of crushed stone, rolled down, and then dusted with stone and sprinkled with water so that the cracks are filled up. Highways for heavy traffic are of concrete, of asphalt, of macadam mixed with tar and pitch, and of specially-treated brick. Sometimes the concrete has steel rods or mesh imbedded in it to make it stronger. The road is a little higher in the middle than at the sides, in order to drain better. On the sides the stone or concrete is thicker because traffic is heavier there than right in the middle of the thoroughfare. Highways are being made wider and wider, as the procession of automobiles becomes more and more incessant. Sometimes there are as many as six or seven "lanes" along which traffic may move, so many cars abreast. Elaborate electrical systems have been worked out to control the movement of traffic along both streets and highways.

Highways in Foreign Lands

Canada adds to her improved highways by hundreds of miles each year. Europe has thousands of miles of magnificent thoroughfares. Good roads are being built in South America. Parts of South Africa have awakened to the need. Even China, where men still starve because there are no good roads from places where there is plenty to places where there is nothing to eat, is making a beginning.

And though it still has a few gaps in the jungles and mountainous wilds of Central America, the Pan-American Highway is nearing completion between the United States and Chile.

And to-day the parade along the roads of the world is something that no old Roman ever dreamed of. He would stare at its size and gasp at its speed. Not on horseback now, or in rumbling coaches, carts, and "buggies" as of old; but in long lines of shining steel cars, nosing each other along like strings of beetles! It may not sound so romantic as the Appian Way or the route of a medieval pilgrimage or even the old Cumberland Road. But the procession carries the life of our age just the same—an age more than ever dependent on its roads.

TRANSPORTATION

Reading Unit No. 5

ON THE WINGS OF THE WIND

Note: For basic information not found on this page, consult the general Index, Vol. 15.

For statistical and current facts, consult the Richards Year Book Index.

Interesting Facts Explained

What the first sails were like, 10–160

How we can go wherever we desire with a sail, 10-160-61

Where our earliest description of a ship is to be found, 10-161

The hardships of the ancient mariner, 10–168

Some famous pirates, 10–170

The square-rigged American merchant vessel, 10–171

When Americans held first place for speed among the sailors of the world, 10-172

The great day of the American clippers, 10–172-73

Things to Think About

How does the sailor tack in the wind?

How did the sailing vessel help to change the history of Europe?

What broke up the trade of the famous clipper ships?

What brought business to the clippers in the mid-nineteenth century?

Related Material

Why do mariners prefer the gyro-compass to the magnetic compass? 10-455-57

What does the great law of Archimedes state? 1–470-71

How well organized was the Roman sea trade? 5-242

How does the wind drive a rotar ship across the ocean? 1-508

How have many ships been saved from being dashed on the rocks? 10–226-29

Of what service is the Weather Bureau to outgoing ships? 1–278

What methods did the Romans use when fighting at sea? 5–212-13

What do the Spanish mean by the term "galley slave"? 10–351

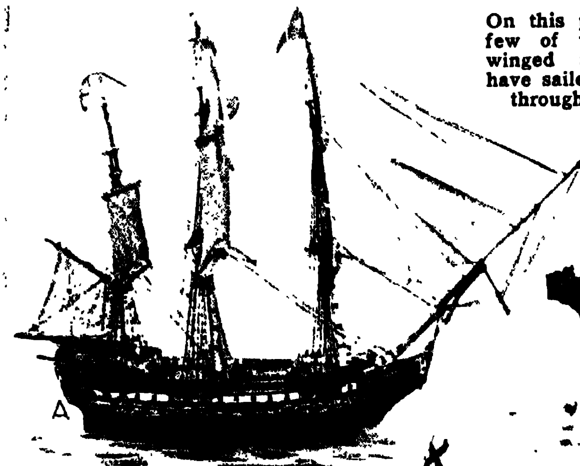
Leisure-time Activities

PROJECT NO. 1: Build a model of a racing schooner, 10–173

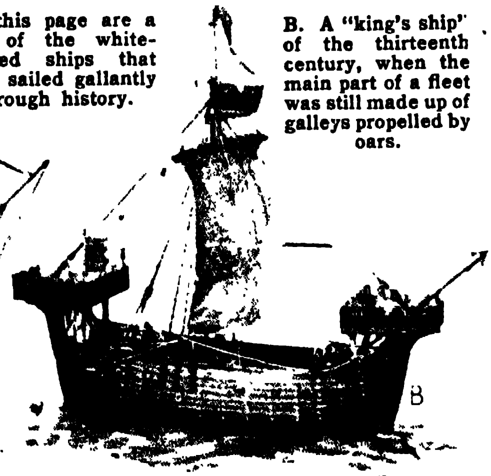
PROJECT NO 2: Read Dana's "Two Years Before the Mast."

Summary Statement

For centuries the sailing vessel has made splendid history, but no matter how good it may be, it can go no faster than the wind, and if the wind does not blow it cannot go at all.



On this page are a few of the white-winged ships that have sailed gallantly through history.



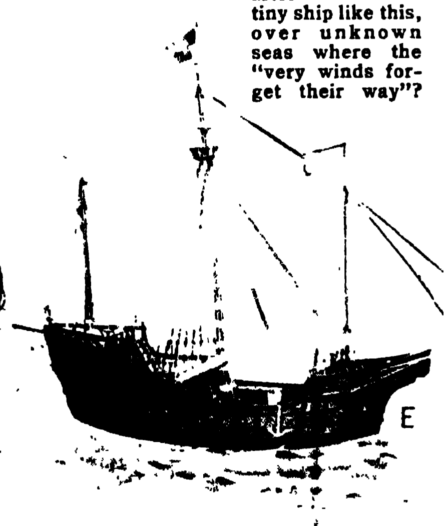
B. A "king's ship" of the thirteenth century, when the main part of a fleet was still made up of galleys propelled by oars.

A. A French privateer of the days when much of the sea fighting among nations was done, not by regular navies, but by boats privately owned and fitted up by this or that great merchant or lord. Sometimes the privateers were as respectable as volunteer soldiers; sometimes they were only pirates under another name.

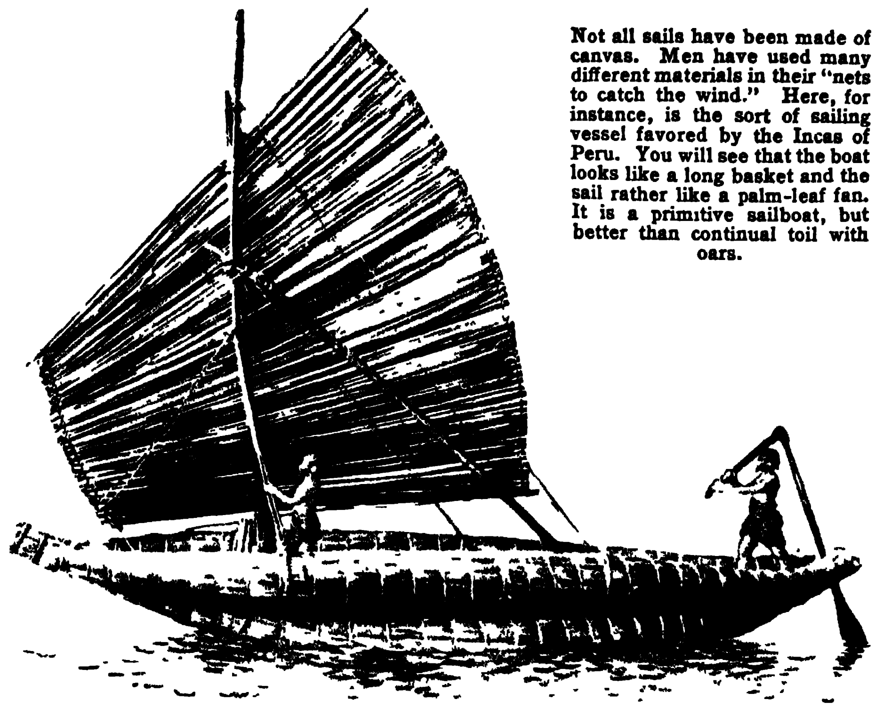
C. The "Mayflower," one of the most famous of all ships, for on it the first little band of English men and women crossed the perilous ocean to New England. They landed late in 1620, after more than two months at sea.

E. The "Santa Maria," one of the ships that carried Columbus and his crew to the discovery of the New World. How can we today imagine that adventurous voyage, lasting week after week in a tiny ship like this, over unknown seas where the "very winds forget their way"?

D. The "Sovereign of the Seas," which lorded it over the waters not long after the time when the Mayflower sailed. She was the largest of the early British men-of-war.



Photos by Museum of Science & Industry



Not all sails have been made of canvas. Men have used many different materials in their "nets to catch the wind." Here, for instance, is the sort of sailing vessel favored by the Incas of Peru. You will see that the boat looks like a long basket and the sail rather like a palm-leaf fan. It is a primitive sailboat, but better than continual toil with oars.

Photo by the National Museum

On the WINGS *of the* WIND

How Men Found Out What They Could Do with Sails on the Water, and How the Sails Made Glorious History

ONCE upon a time, many and many a century ago, a man who was about to drown in a raging river grabbed at a floating log and went on down the stream in safety. Whether he knew it or not, he was the first sailor in the world.

If he was a genius, he may have had a great notion pop into his head. It was nothing less than the notion of keeping a log or two to bear him afloat on the dangerous waters and to carry him down the river when he wanted to go. If so, he owned the first of all navies. But almost certainly he was no sort of genius, and the world had to wait a long time yet for the inventor who first kept a log, or a little fleet of logs, for such a purpose. Then the world may have waited a long time still for another genius who hollowed out his log and so made a dugout, or the first boat; and much longer yet before this one-log boat was surpassed by a boat built and shaped of various boards fastened together. When we get to a boat built in that way, we are already fairly far down in the history of our race.

About all that, we have told in our story called "Before We Ever Had a Sail." For of course the next great invention was the sail. It was such a mighty invention that we must start another story about it. The importance of it can hardly be overstated; as we shall see, the unknown genius who invented the sail made the world into a different kind of place. He made nearly as much history as any other man who ever lived.

What happened must have been something like the following: That unknown genius noticed, as others had noticed before him, that the wind pushed his boat ahead, or sidewise, just as well as did the current of the river, or the action of his oars. He found that when he stood up in the boat, the wind

pushed harder. If he placed a thick bush in the boat, it pushed harder still; and if he stretched some sort of skin on some sort of mast in the boat, then the wind pushed very hard indeed. It carried him along as he had never traveled before. And from now on the genius stretched a skin to catch the wind.

The First Sail

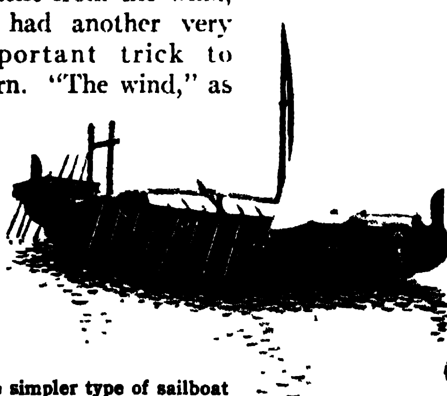
That skin was the first sail. It was the parent of all the vast stretches of canvas with which our ships have been rigged from that day to this, just as the boat that carried it was the parent of every sailing ship that the world has since seen. The vast things that we have done with sails and sailing ships in the centuries since that early day have all been simply improvements on that first sail and on the kind of boat that bore it. We have made the sails far larger, far more numerous, of far better materials; we have learned a vast number of devices for rigging them and handling them; we have fitted them to every kind of wind, from a gentle breeze to a hurricane, no matter which way it was blowing; and we have built much larger and much better ships, to carry more and more sail. But at bottom the aim has always been the same—to put up sails that would get the greatest possible benefit from whatever kind of wind was blowing.

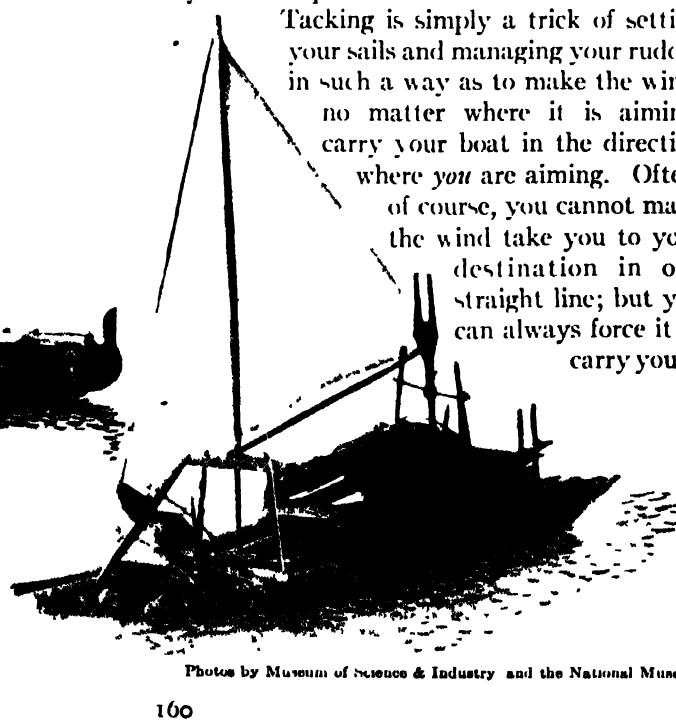
Yet before a man could get much real benefit from the wind, he had another very important trick to learn. "The wind," as the Good Book tells us, "bloweth where it listeth." At any time it may be blowing just opposite to the way you want your boat to go, and almost never will it be blowing exactly toward the point you want to reach. And it is always changing its direction from day to day, or from hour to hour. You might have to wait for days before the wind was "right" to take you across a river; and how often do you think it would stay "right" long enough to take you the length of the Mediterranean? That would practically never happen. And even when it did happen, the wind would probably land your boat a few hundred miles away from the place you wanted to reach.

What Is "Tacking"?

So man had to find some way of using the wind without being at its mercy. Just when it was that he found the way we do not quite know, but he certainly discovered it fairly early. He simply found out how to "tack" in the wind. As soon as he knew about "tacking" he could use any wind to take him in any direction. He could sail precisely to the point he was aiming at. He could sail with the wind, or sidewise to the wind, or right into the teeth of the wind, just as he pleased.

Tacking is simply a trick of setting your sails and managing your rudder in such a way as to make the wind, no matter where it is aiming, carry your boat in the direction where *you* are aiming. Often, of course, you cannot make the wind take you to your destination in one straight line; but you can always force it to carry you in





The simpler type of sailboat has not changed much in six thousand years. Above is an Egyptian sailing vessel of about 3600 B.C., and to the right is a little boat still used in Brazil to-day. The modern boat is considerably more primitive than the ancient one.

Photos by Museum of Science & Industry and the National Museum

a zigzag course until you get there. If you know the trick—and it is so simple that any child can learn it easily—you are the master of all the winds that blow. You can go wherever you desire with a sail.

Now all these things men had found out very long ago. Once they knew them, they were ready to begin ranging the stretches of the waters. They had the power of the wind behind them, in place of the power of their rowing muscles; they had the trick of tacking, or of keeping to their aim, and they had the stars to steer by. The history of exploration, of trade and travel, was well under way; and the rest of our story is about what came of it all.

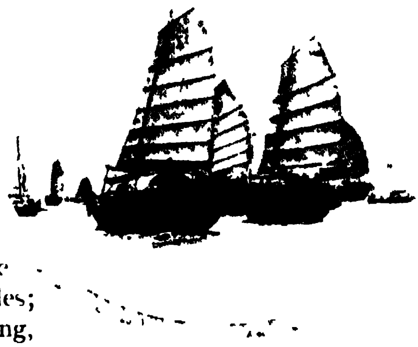


Photo by American Museum of Natural History

These big boats, with their sterns built high and four-sided sails stiffened with light strips of wood are Chinese junks, still to be seen in the Orient.

Probably our earliest description of any ship is found, not on a piece of paper or parchment, not even on a carven stone, but—of all places—on a painted vase. The vase was made by fingers that have now been dead for perhaps six or seven thousand years. It was dug up in Egypt, and the ship that is traced on its sides was an Egyptian ship, of the kind that used to sail up the Nile some four thousand years before the birth of Christ. That ship carries a mast for a sail, to help the rowers along for during many centuries after the coming of the sail, the ships would very often have both oars and sails.

The Egyptians were such an amazing people that by the year 1500 B.C. they had carried the business of shipping to the point where they needed and built a canal from the Nile to the Red Sea. About this time their land was ruled by a queen. Her name was Hatshepsut (hat-shĕp'sōōt), and she was the first great woman in history.

Having certain advanced ideas about trade, she sent out an expedition of five ships to the land of Punt (pōōnt), probably what is now Southern Arabia. They went up the Nile from Thebes, through the canal, and then down the Red Sea, carrying fine gifts to the king of Punt and his fat little wife. They brought home sweet-smelling woods and all sorts of new plants, they brought ivory and gold and leopard skins, as well as dogs and apes and slaves. And they brought back the dumpy queen of Punt herself, for a visit to Hatshepsut. So the great queen of Egypt was so delighted with the enterprise that she had pictures of the ships, cargo, live stock, and visiting queen carved in the stone of a temple at Thebes, together with a story of the expedition. There we may see the pictures and read the story to this day.

The ships were sixty feet long, had fifteen pairs of oars,

Such boats as this plied up and down the Nile many centuries before Christ. We know what they looked like from little models, like this one, which the Egyptians buried with their dead.

Photo by Metropolitan Museum of Art

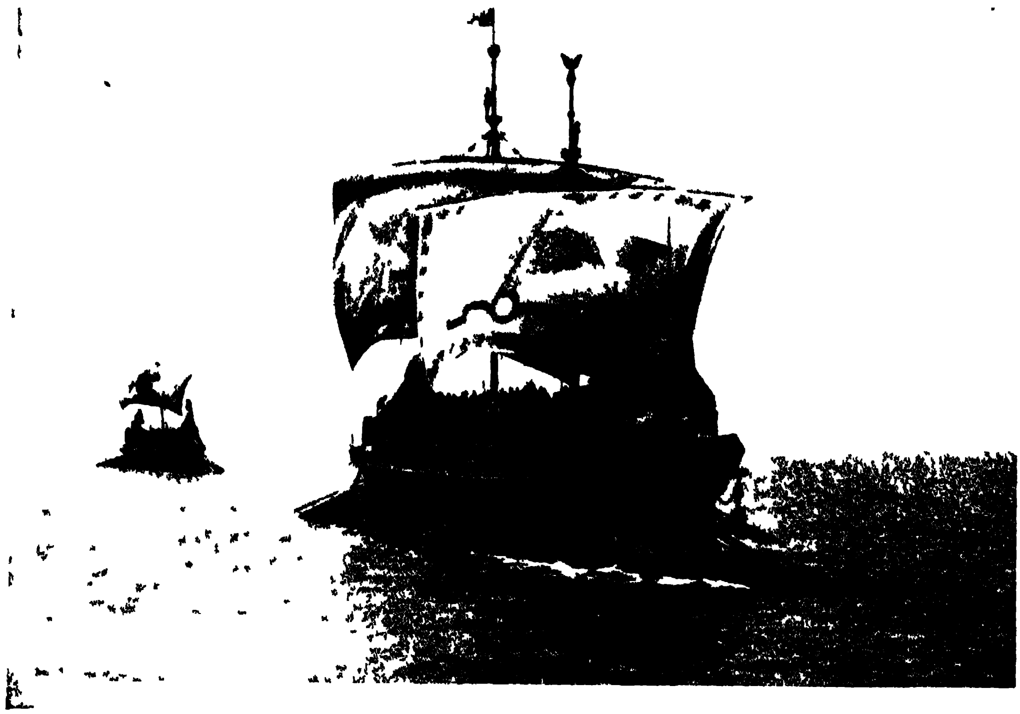


Photo by Metro-Goldwyn-Mayer

In the proud days of Rome her galleys ruled all up and down the Mediterranean, that great inland sea about which Western civilization centered. Many were the stately triremes like the ones above that patrolled the waters, their oars moving in perfect rhythm, their sails flaunting the Roman eagle to the breeze.

and carried large square sails At the bow a man with a sounding pole gave warning of shoals or helped to keep the ship's head away from rocks At the stern were three men with steering paddles, and in the middle stood an officer with a whip to keep the oarsmen at their work That was the way the Egyptians skimmed over the waters

The Great Sailors of Antiquity

But they seldom went very far, for the Egyptians were not a seafaring race That honor belongs to the Cretans among the ancient peoples, and far more still to the Phoenicians (fē-nĭsh'ăn), who were by all odds the greatest sailors of their day. In our story of this people we have told how, living in a narrow strip of land between the mountains and the Mediterranean Sea, they came to do most of the carrying trade in the world as early as 1000 B C. The ships from their cities cut through the Mediterranean in every direction, carrying the luxuries of Egypt and the East as well as the products of the Phoenician craftsmen— tempting their customers with fine clothing and jewelry, with silver and porcelain dishes, cunningly wrought toilet articles, mirrors of polished silver and gold, and delicate perfume bottles of glass and alabaster

The Phoenicians had the secret of making famous purple dyes from the shellfish on their coast, and their sailors collected high prices for the precious "Tyrian purple." The list of their further wares reads like a poem: perfumes and spices coming by caravan from India and Arabia; amber from the Baltic and the far North Sea, fine woods and copper from Cyprus; silver and iron and tin and lead from Spain and distant Britain—and in such abundance that the very anchors of returning ships were fancifully said to be made of silver. Then there were brass utensils from Grecian Ionia, ivory and ebony from around the Red Sea, gold from Ophir—perhaps in Arabia—embroideries and linens,

emeralds, agate, and coral from Syria, wheat and honey and oil and balm from Judea, wine and white wool from Damascus, and many another thing of use and beauty from many a corner of the world. With all these, of course, went the still greater gift of the Phoenicians to the world—that alphabet which has come down for us to use to-day.

The Watery Trail of Civilization

Now what the Phoenicians did in carrying goods and in planting colonies—Carthage was only their most famous colony shows how important the sea ways were becoming in the history of mankind. For a long time the roads of the sea were far more important than those over the land, and they are of the highest importance still. Overland an ancient country might be shut off from the world by mountains and by deserts through which hardly any man could pass. The sea was open. It long ago became the main path of the trader and traveler, the chief highway of civilization. It was the sea roads that knit the world together long before the land roads were good enough to do so. It was mainly over the waters that every part of the known world got the products and the culture of all the other parts. It was across the waters, in a word, that civilization spread. And it goes without saying that the more they had to carry or the more they had to fight, the larger and more capable the ships became.

The Phoenicians did not do all this with sails. They would use both oars and sails in the same ship, and they were likely to employ the sails only when the wind was with them. In a word, they acted just as did many a seaman after the coming of steam—for he often put both sails and a steam engine on his boat. And like the Phoenicians, the Greeks and the Romans often used both oars and sails when they came in turn to be the masters of the sea. In general they used oars in their warships and sails for their merchant vessels, though they often employed both kinds of power.

For though we said a moment ago that as soon as the seamen had sails and knew about tacking they could go anywhere, we must not suppose that the Greek and Roman merchantmen often ventured far into the deep. They usually hugged the shores for safety, however far out of their way the coast line might be to them; and their voyages were usually pretty slow, compared with anything we know to-day.

In fact, the Greeks and Romans were more remarkable for their great rowing ships than for their sailing ships, especially for those they built for war. We ought to pause a moment over these before going on with our story of the sails.

There is probably no man alive to-day who would know how to build a boat just like the biggest ones in the Greek or Roman navy. These boats depended on the muscle of the man at the oars; and for speed and power it was soon found that a single tier or "bank" of rowers was far from enough. First a boat was made with two banks of oars, one above the other. That was called a "bireme" (bī'rēm), which means simply "double-oared." Then came the trireme (trī'rēm), with three banks of rowers; the quadrireme (kwŏd'rĭ-rēm), with four banks; and the quinquereme (kwĭn'kwē-rēm), with five. You must be already wonder-

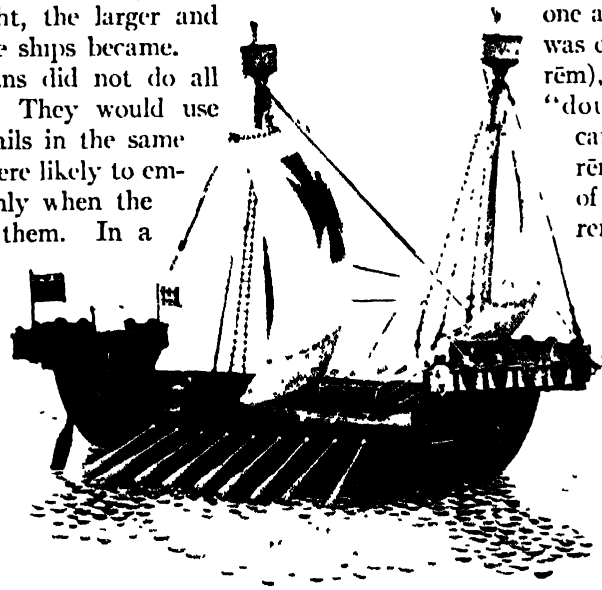


Photo by Museum of Science & Industry

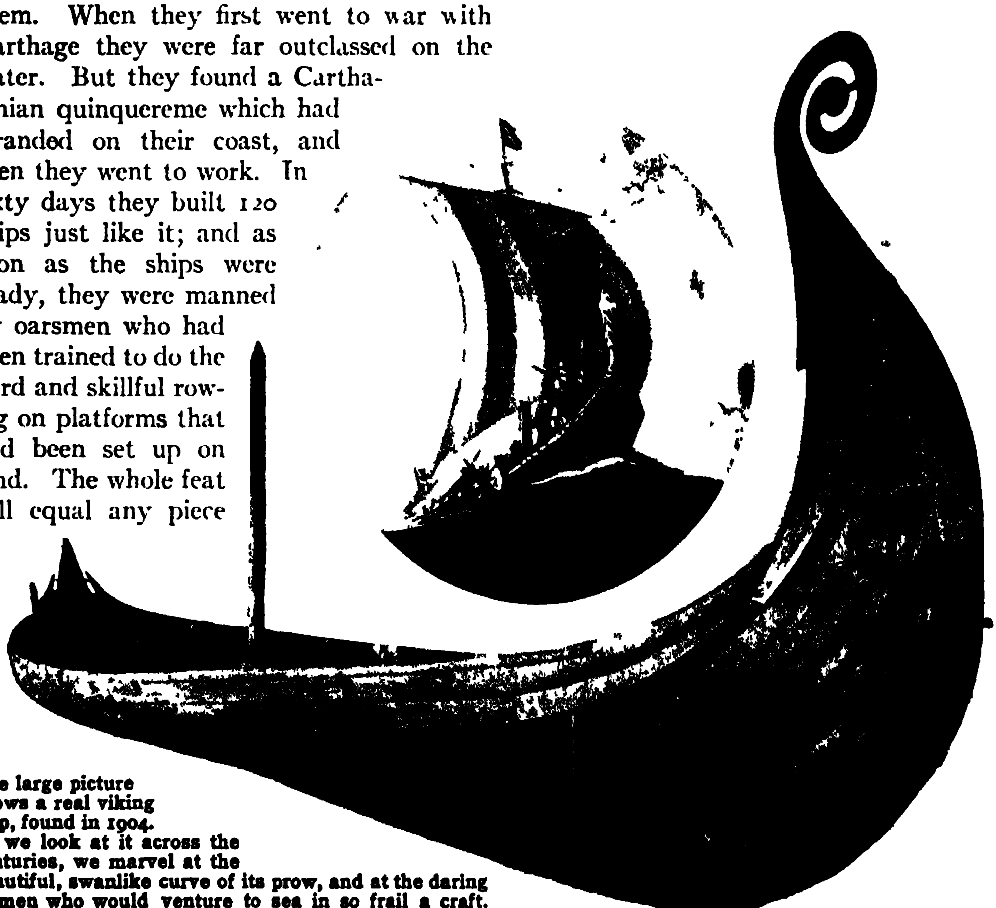
In such ships as this the Normans must have come to conquer England. The boat is a galley, as you see, and carries both sails and oars.

ing how a boat could be made for five sets of rowers, one above another, with every man in each set reaching the water with his long oars. But the boat builders did not stop there. They went on to make six and seven banks; and before they were through they actually had boats with as many as sixteen banks of rowers. Now how would you build a boat so that the sixteenth set of oarsmen, atop all the others, could still dip their oars into the water and scoop through it?

How Rome Became a Sea Power

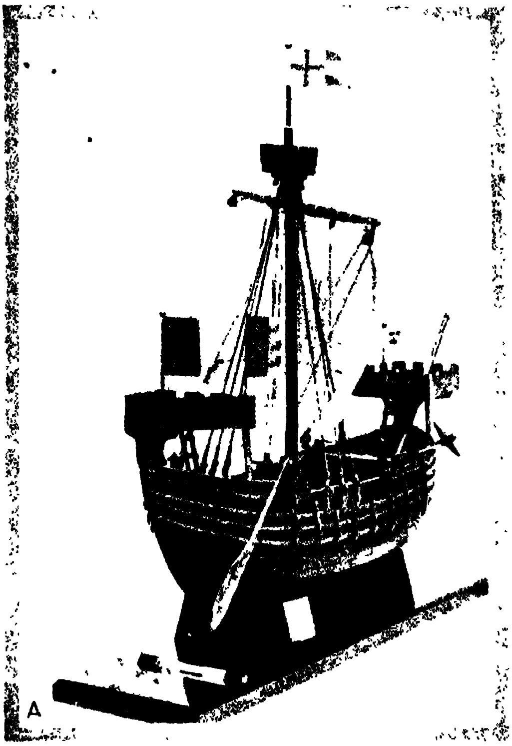
These were very powerful ships, and they gave Rome many a victory. They helped her Romans to ruin Carthage and to master a great part of the rest of the world. These Romans, to be sure, had not started as a seafaring people, but they had a great way of picking up the inventions and the secrets of other peoples and making the most of them. When they first went to war with Carthage they were far outclassed on the water. But they found a Carthaginian quinquereme which had stranded on their coast, and then they went to work. In sixty days they built 120 ships just like it; and as soon as the ships were ready, they were manned by oarsmen who had been trained to do the hard and skillful rowing on platforms that had been set up on land. The whole feat will equal any piece of modern "efficiency" we are likely to see. It was the beginning of the end for Carthage.

All of these great ships with oars are called galleys, and the galley lasted, along with the sailing ship, straight through the Roman era and down through the Middle Ages. It changed considerably in form, and came in general to have fewer banks of oarsmen than in the biggest boats of old. But always it depended on the power of the human arm It made a terrible life for the oarsmen who had to man it. The work was grueling, and was often done under the lash. It was dangerous in peace as well as in war; for the mere task of baling out the water that was always spilling into the ship was a heroic one. The rowers were commonly slaves or criminals who were set at the work for punishment. There have probably never been wearier muscles in the world than those in the backs of the wretched galley slaves, and

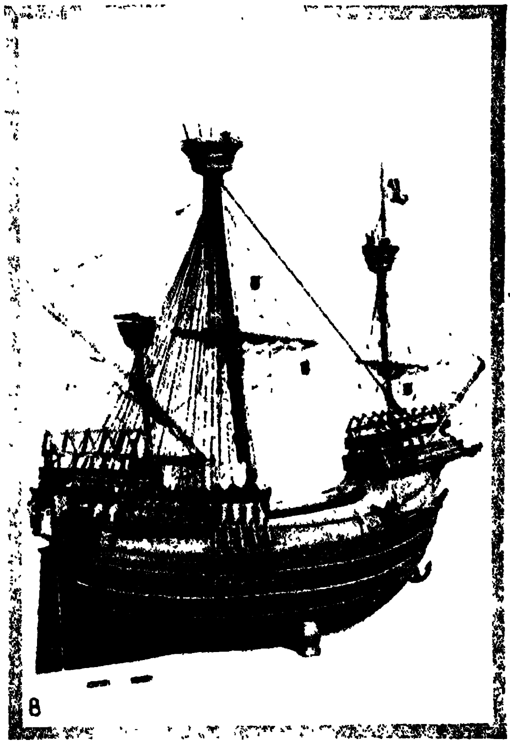


The large picture shows a real viking ship, found in 1904. As we look at it across the centuries, we marvel at the beautiful, swanlike curve of its prow, and at the daring of men who would venture to sea in so frail a craft. The picture in the circle shows how one of these "dragon ships" must have looked in its prime.

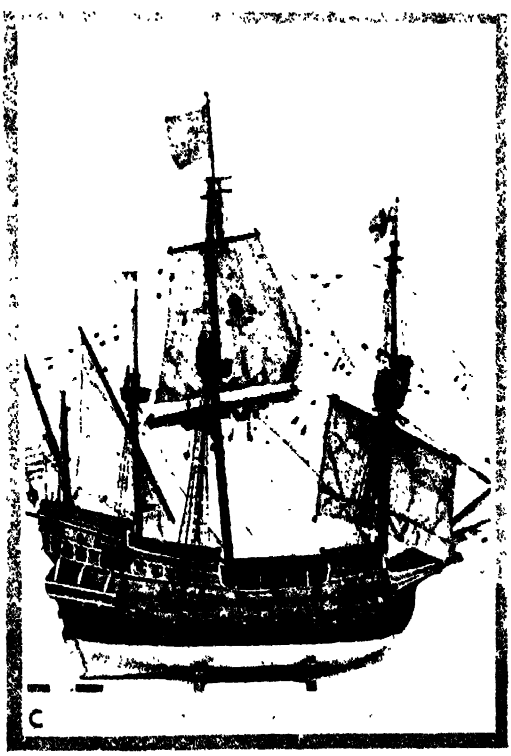
Photos by O Varing, Oslo



Model of a seagoing vessel of the 1200's.

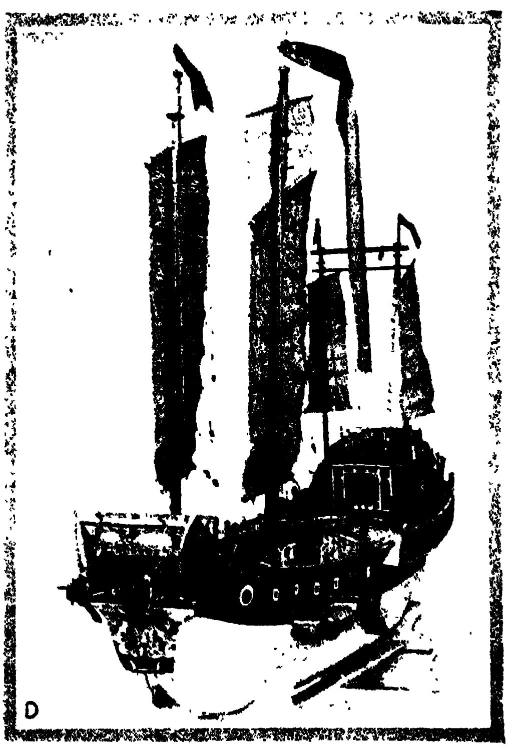


Flemish carack, or large merchantman, of about 1480.



Photos by Science Museum, London

English man-of-war of the time of the Armada (1588).



Large Chinese junk, sails and banners flying.

there have been few kinds of punishment worse than being "condemned to the galleys." Sometimes the oars were so big and long that it took three or four men to pull one oar through the water, and sometimes the men had to be chained to their oars to keep them in the boat. There is hardly anything more horrible in the history of man than the long story of the galleys. Lasting through the Middle Ages, they even saw cannon mounted in their stout timbers. But they finally gave way completely to the sailing ship.

We have strayed away from the tale of the sailing ship, and now we must go back. For the Romans had many a sail ship too, mainly for travel and for trade. These took the Roman governors and armies all over the provinces of their vast empire; and they brought to Rome the food and luxuries that came from every quarter of the world. It was still a dangerous thing to go to sea. No man could yet build a boat that might not go down in a storm, and no traveler be sure just when a pirate boat might cross his path. But still the Mediterranean was full of sails, at least along all the coasts, and the ships were constantly getting larger and stronger. By the time of the first Caesars a big Roman ship might carry three hundred persons, or even more, from Rome to Egypt.

Here is a map to show how hard it was to get from Europe to Asia by sea before the building of the Suez Canal. Many times during the last four thousand years some enterprising person, usually a ruler of Egypt, has built a canal eastward from the Nile at least part way to the Red Sea. But these canals always filled in again; and they made an incomplete and purely Egyptian route, anyway. Not until 1867 was there a way for seagoing ships of all nations to sail directly from the Mediterranean to the Red Sea. The canal we use now was dug by the French, but it is governed by a group of men from England, France, and Holland, and is open to all the world. Meanwhile, in the centuries before it was opened, thousands of ships had gone back and forth between Europe and Asia by the long route around the southern tip of Africa.

During the long period of the Middle Ages there was no vast change in such ships. The vikings of the north, sailors as bold and skillful as the world has ever seen, arose to be a famous terror of the deep. At the height of their power, from the seventh century to the eleventh, they harried and plundered every coast in Europe. In their long boats, equipped with both oars and sails, they made their way into the Mediterranean and even went as far as Constantinople where the ruling prince was glad enough to make peace with them at a high price. They set up a colony in Iceland, and another one in Greenland; and one of them, Leif Ericsson, is now known to have sailed all the way to the coast of North America.

The vikings were very remarkable shipbuilders, for they studied all the ways of the sea and made their ships to master it. They gave their boats very poetic names- "Deer of the Surf," "Lion of the Waves," "Raven of the Wind," "Long Serpent," "Dragon." And we can see now just what those boats were like, from the ones that have been dug up out of the ground in Scandinavia. In such ships the Angles and

the Saxons doubtless came to England, and in such ships William the Conqueror certainly took his Norman soldiers across the Channel.

There were other great naval powers in the Middle Ages, especially in the time of the crusades and later as the trade with the East grew to great proportions. The cities of Genoa and Venice led in this, though other lands often had a good share. In the crusades vast numbers of soldiers and vast quantities of supplies had to be carried toward Jerusalem, and the ships sprang up to do the work. In the Eastern trade great fleets of vessels were busy bringing to Europe the treasures and luxuries, the silks and spices and precious stones, that were always pouring westward across Asia through the routes of the caravans. To this very day the city of Venice bears a thousand marks of the glory she enjoyed centuries ago when her sails were straining before every wind of the Mediterranean, bearing rich and coveted cargoes to the Western world.

Yet it is not until the end of the Middle Ages that the greatest romance of the sailor and his ship begins. Then the Turks had conquered all the pathways to the East, and the rich trade was cut off. Between the two vast continents of Africa and Asia was a little strip of land at Suez (sōō-ĕz′). A man could walk across it fairly easily, yet no ship would ever get through it without a canal. And just because of that little strip of land a ship would have to go all the way around Africa to get to India, or sail west all the way around the world! There was no other way to keep up the Eastern trade, so long as the Turk stood his ground in Asia Minor. But now that they had a compass to steer by, the sailors of the West set out for India in whatever way they could.

The vast romance of the sailing ship came with this effort to get to India, and with what followed it. You know all the story, and we have told it all in other places in these books. You know how Prince Henry the Navigator built up a fleet of prize vessels and trained skillful seamen to sail farther and farther down the African coast; how Bartholomew Diaz (dē′äsh) finally made his way around the southern tip of the continent; how Vasco da Gama went around the Cape to India; above all, how Columbus set sail to the west and found another half of the world; and how, among many hardy followers of these, the brave Magellan made his sails encircle the globe.

This graceful ship is an American ketch, or strong, two-masted vessel, built in 1713.

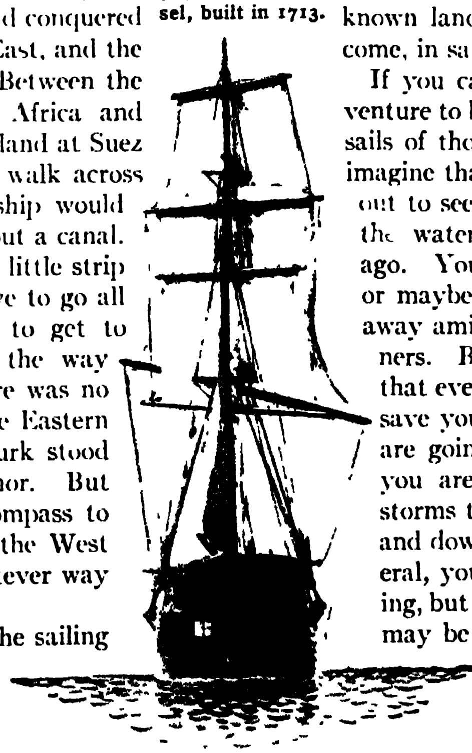


Photo by the National Museum

The Age of Adventure

These were deeds that would have made the old Phoenicians stare and gasp. And what followed was a great building of fine sailing ships and a great list of explorers and traders in the riches of the New World. No adventures on the seas had ever been equal to the ones that now came, no such stores of gold and treasure had ever been carried under sail, and no such heroism had been shown or such hardships endured as in the ships of the captains who sailed forth into unknown seas to search for unknown lands. The modern age had come, in sailing as in all other things.

If you care for a taste of the adventure to be had under the spreading sails of those days, you may as well imagine that you are a captain going out to see what you can find across the waters of four hundred years ago. You have a fine, stout ship, or maybe two or three, as you sail away amid cheers and waving banners. But you know well enough that even this strong ship may not save you in every storm, and you are going to be out so long that you are sure to meet plenty of storms that will toss your boat up and down like a sea shell. In general, you know where you are going, but you have little notion what may be in your way—what rocks and shoals, what coral islands, what icebergs, what contrary winds. Even with your compass

Photo by Autotype Fine Arts Co. Ltd.

Mutiny on the high seas! Let the officers lock to it now or they may find themselves prisoners in the hold of their own ship, or abandoned on a desert island, or facing some more sudden death. Far away from land or word of land, in a little world of their own in the midst of the waters, the sailors might well have taken matters into their own hands much oftener than they did. For the seas were lonely and perilous, the life was very hard, and too often the masters were brutal. Sometimes, too, it must have seemed to the sailors that their captain was mad. Columbus was threatened with mutiny. Henry Hudson was set adrift on Hudson Bay. Yet how many more times the men stuck stoutly to their posts and brought the ship to port!

to guide you, and with all your skill with sails and rudder, you may be driven hundreds of miles off your course by bad winds. You may turn up on some desolate, uninhabited shore instead of on the gold coast you are aiming for; or you may reach some spot where the savage natives cut you to pieces and even eat you.

Hardships of the Ancient Mariner

You may have to loll about in the waves for days and weeks at a time, without making an inch of progress, because there is no wind. All that time, and all the rest of the time, your provisions will be dwindling. You have brought all the food you could stuff into your good ship. But the months have passed, and your stock may be very low. Maybe it is all gone, and you and your men are reduced to eating leather and sawdust and any rats you can catch on the ship. You could not bring along any fresh food, because it would not keep; and so now the terrible disease of scurvy has broken out on your ship, and half of your men are dying. Perhaps four of them in five will be dead before you ever get back home.

You picked these men as carefully as you could, of course, before you started. But you did not have all the choice you would have liked. Very few of the sailors at home would dare to go on such a perilous voyage. You took the strongest and hardiest men you could find among those who were bold enough to go. Just because they are such hardy adventurers, they are anything but meek Christian gentlemen; the fact is that they are a lot of very "tough customers."

The buccaneers were such colorful villains that it is very hard to condemn their villainy with the proper conviction. And indeed some of them were gentlemen in their own odd way, and most of them were fearlessly brave. But suppose they boarded your boat—as in the picture—and slashed to right and left till scarcely one of your men was alive and you yourself were a prisoner. Then it would be much harder to see how romantic the buccaneers were—and much easier to see that they were villains!

For a long time they have been frowning and muttering. You have noticed little knots of them whispering together and looking askance at you. And now that they are down to leather and sawdust, with a rat once in a while, you know your danger. There may be a mutiny. In that case you are very likely to go overboard as the men take over the ship and head for home—if they know the way.

The Reward of the Adventurer

Still there is a pretty good chance that you will get through all your troubles and reach home again. If you do, you will have a tale for your grandchildren. You could write a book. Maybe you will come home with a ship full of gold, maybe you will not have a nugget. Maybe you will have found new coasts and islands, and new places for flourishing colonies, or maybe you will have to say that you have seen nothing but water everywhere. Maybe your king will hang a gold chain around your neck and make you a nobleman, or maybe he will put an iron one around your ankles and throw you into jail. You are never very sure, but anyhow you have your vast adventure, like a thousand other captains.

About the time of Columbus, the great sea powers were Portugal and Spain. But England, France and the Netherlands were rising into fame for their ships and sailors. For a hundred years or so they were all trying to get the best of their great enemy, Spain, though they afterward fell out with one another. They fought Spain in the Old World and the New World, and they fought her on the high seas. Many a bold captain like Francis Drake was prowling the seas to

waylay any Spanish ship laden with treasure from America, and the governments of the day winked merrily at all his piracies. All that is part of the romance of the sailing ship, too, though it does not always make a beautiful romance.

And then came a great system of piracy that was far worse. It rose with the bold buccaneers in the Caribbean and ran a great course all through the seventeenth century. Some of these pirates had been slaves to the Spaniards, and they kept their hatred of their masters ablaze after they gained freedom. Others were sailors who had deserted or had mutinied. Some were just adventurers out for an easy living. Most of them were French or English.

Who Were the Buccaneers?

They started their nest on the island of Hispaniola (hĭs′păn-yō′lȧ), now Santo Domingo. The natives there had been killed off by the cruel Spaniards, and the island was full of herds of wild cattle. The outlaws hunted the cattle and cured the meat after a fashion they had learned from the Carib Indians—in strips on grills over slow fires. The grills were called "boucans" by the Indians, and so the outlaws got the name of "boucaniers," or "buccaneers." Now Spain forbade anyone to buy goods in this region except from the Spanish. So the buccaneers, who wanted to sell their cured meat, grew into smugglers, and of course hated the Spanish more and more all the time. Finally they secured ships; and they would lie in wait along what people have come to call the "Spanish Main," meaning by that the path of the merchantmen of Spain through the Caribbean. At every chance they would seize a proud galleon on its way home, full of gold and jewels.

Famous Pirates

There were many famous pirates. One of them was John Avery, otherwise known as Bridgeman, long a terror of the sea. Another was Bartholomew Roberts, who is said to have captured about four hundred ships from first to last. There were even women pirates. But the most famous of all pirates in popular legend may not have been a pirate. That was Captain Kidd. He was hanged for piracy in London, but his trial has left doubt in the minds of many as to whether he really deserved such a severe punishment.

At the beginning of the eighteenth century England made a determined effort to

For generations England and Holland were rivals for control of the seas. It is said that Tromp, a Dutch admiral of the seventeenth century, hoisted a broom from his mast "to sweep the English from the sea." The English admiral replied by hoisting a whip. In this picture the designer is showing a model for a new British warship—"A New Whip for the Dutch."

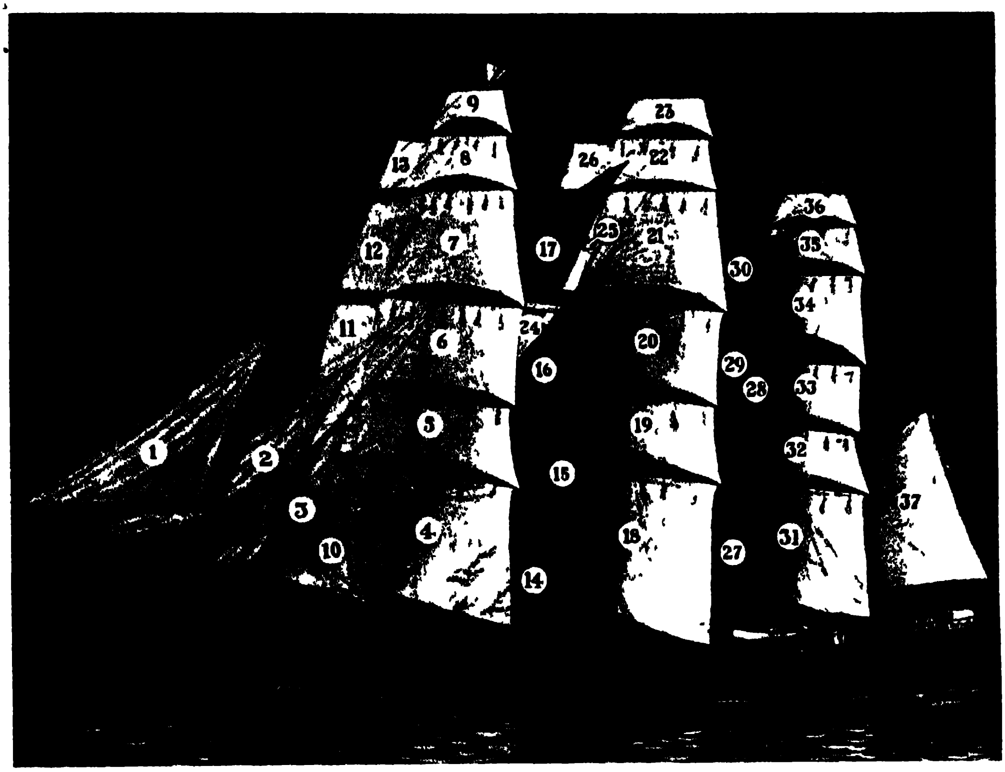


Photo by the National Museum

This is a square-rigged American merchant vessel, with all sails spread. Thirty-seven of them! How many do you know? Here are the salty-sounding names of all of them: (1) flying jib; (2) jib; (3) fore-topmast staysail; (4) foresail; (5) lower fore-topsail; (6) upper fore-topsail; (7) fore-topgallant sail; (8) fore royal; (9) fore skysail; (10) lower studding sail; (11) fore-topmast studding sail; (12) fore-topgallant studding sail; (13) fore-royal studding sail; (14) main staysail; (15) main-topmast staysail; (16) main-topgallant staysail; (17) main-royal staysail; (18) mainsail; (19) lower main topsail; (20) upper main topsail; (21) main-topgallant sail; (22) main royal; (23) main skysail; (24) main-topmast studding sail; (25) main-topgallant studding sail; (26) main-royal studding sail; (27) mizzen staysail; (28) mizzen-topmast staysail; (29) mizzen-topgallant staysail; (30) mizzen-royal staysail; (31) mizzen sail; (32) lower mizzen topsail; (33) upper mizzen topsail; (34) mizzen-topgallant sail; (35) mizzen royal; (36) mizzen skysail; (37) spanker. Now if you have read these names you have doubtless noticed that most of the sails are named for the mast on which they are hung– the foremast, which is in the bow; the mizzenmast, in the stern; and the mainmast, between them. The sails take their names from their position in the mast. On any square-rigged vessel the sails are hung from strong horizontal supports called "yards," and each yard is suspended—or "slung"– at its middle point from the mast. When the ship is sailing with the wind squarely behind her—"before the wind"—the sails are spread at right angles to the keel of the boat. When a square-rigged vessel carries triangular sails, they are hung on heavy ropes called "stays." A fore-and-aft rigged vessel carries one large sail to a mast, and this is attached—or "bent"—to large spars or stays in the midship line of the boat. For the term "fore-and-aft" means "lengthwise of the vessel." A sail spread in this way can swing to either side of the mast or be set behind the mast on a line with the axis of the boat. A two-masted boat that is square-rigged is a brig. A schooner is a fore-and-aft rigged boat with two or more masts and a jib. Such a boat with only one mast is a sloop—unless it has a second smaller mast, in which case it is a yawl. Sometimes vessels carry both square and fore-and-aft rigging. A brigantine is square-rigged on the fore and the main, except that the mainsail is fore-and-aft rigged. A three-masted vessel with square rigging on the foremast only is a barkentine; if it has square rigging on all but the mizzenmast, it is a bark.

root out the buccaneers, and most of them disappeared. Some of them kept on, however, and it was not till about a hundred years ago that the last of them vanished. They could not stand against the steamship.

After the great days of Spain, several other nations gained or disputed the rule of the ocean. The palm finally came to England, who steadily grew as a naval and trading power from Drake's defeat of the Spanish Armada (är-mä'då) in 1588 to Nelson's victory over Napoleon's navy at the Battle of Trafalgar (trå-făl'gär) in 1805. From then until World War II, when the United States took first place, England was the world's leading sea power.

Photo by New York Trust Co

A ship entering New York harbor! Yes, but it happened a long time ago, when our great city was the small Dutch seaport of New Amsterdam and when ships were still dependent on the winds

Yet there was a time when the Americans held the first place, at least for speed, among the sailors of the world And by way of telling what the sailing ship had grown to be like in its lordliest days, we may say a word about the famous clipper ships, first built in the United States They came after the steamboat was already on the ocean For the sailing ship had its proudest moment just before it made its final bow to steam.

The Speed of the Famous Clippers

These famous clipper ships passed everything on the ocean, even the steamboats of their time. By 1843 clippers built in the yards of Boston and New York and Baltimore were speeding back and forth between China and England and the United States, laden with tea. In those days of fewer delicacies tea was considered a great luxury, and people were most exacting about its quality. It was thought that tea lost some of its flavor on a long voyage, and the first of each year's crop was at a premium on the London market So speed was important for the ships that brought it—and speed the clippers made When there was a favoring wind the captain was on deck day and night Sometimes the sails were padlocked to the masts so that no matter how frightened the sailors might be in a terrific blast, the canvas could not be hauled down. The ships raced each other. In the most exciting of all these races, five British clippers sailed out of Foochow bound for London The winner was the "Taeping," which got home twelve minutes ahead of the "Ariel," second in the race

Most popular perhaps of all the clippers of the United States was the "Flying Cloud," a thing of beauty and grace and speed built by Donald Mackay, one of the greatest of all the American shipbuilders. She was 1,783 tons register, 220 feet long, and 40 feet, 8 inches in the beam. Her mainmast was 88 feet tall and her main yard 82 feet. When she made the trip around South America from New York to San Francisco in 89 days

and 18 hours, the whole country was filled with pride, and her owners had the log of the voyage printed in gold on white silk to distribute among their friends. Her record was 374 miles in 24 hours. That was a record that steamers did not reach till more than twenty years afterward, and it is a good record for the average steamer on the ocean to-day. But the "Lightning," Boston-built and manned with British sailors, made 436 miles in 24 hours.

The discovery of gold in California in 1848 and in Australia three years later brought business to American and British clippers. In America men were frantic to get out to California. The overland journey was slow and dangerous. The way around the stormy Horn was faster, though perhaps even more dangerous. Any ship that could stand up at all on the sea could count on passengers for the Pacific coast. It was easy enough to get a crew for the trip out, but a very different thing to get one to sail back again. The moment a ship landed in San Francisco, everyone on board was off on a mad search for gold. Sometimes even the captains grew delirious with gold fever and left their ships to rot at the wharves while they went digging for treasure. But not the captains of the clippers! They sailed back around the Horn as fast as they could go, to pick up another load of passengers; or they made off across the Pacific after cargoes of tea for London or New York.

The great day of the American clippers was between 1850 and 1860. After that the Civil War and and competition from the British merchant seamen and from steam vessels combined to break up their trade.

Nowadays we see reminders of those gallant sailing ships in the best of the little models, clippers in miniature, and in the long lines and raking masts and spreading sails of racing yachts.

The clippers were not built for passengers. Ocean travelers at that time went mostly in packet ships, which built up a fine service between the United States and Europe. The Black Ball Line had regular sailings on the first and sixteenth of each month from New York to Liverpool. That line got its average down to twenty-three days over to England and forty days back. The record was held by the "Canada," which made a voyage in fifteen days and eighteen hours. One of the great packet-ship matches was sailed in 1837 by the liner "Columbus" against the "Sheridan." The stake was $10,000, and the "Sheridan's" crew were promised $50 apiece besides their pay of $25 if she were the winner. But the "Columbus" made it from New York to England in sixteen days, and the "Sheridan" was two days behind her.

Yet in the end packets and clippers had to give way to steam. For no matter how good a sailing vessel may be, it can go no faster than the wind, and if the wind does not blow it cannot go at all. It can never be certain when it can start or when it will arrive. Yet the sailing ship could give way gracefully and with pride. For centuries she had made splendid history and had won a place in the imaginations of men from which she can never be displaced by the smartest ocean greyhound or the mightiest man-of-war.

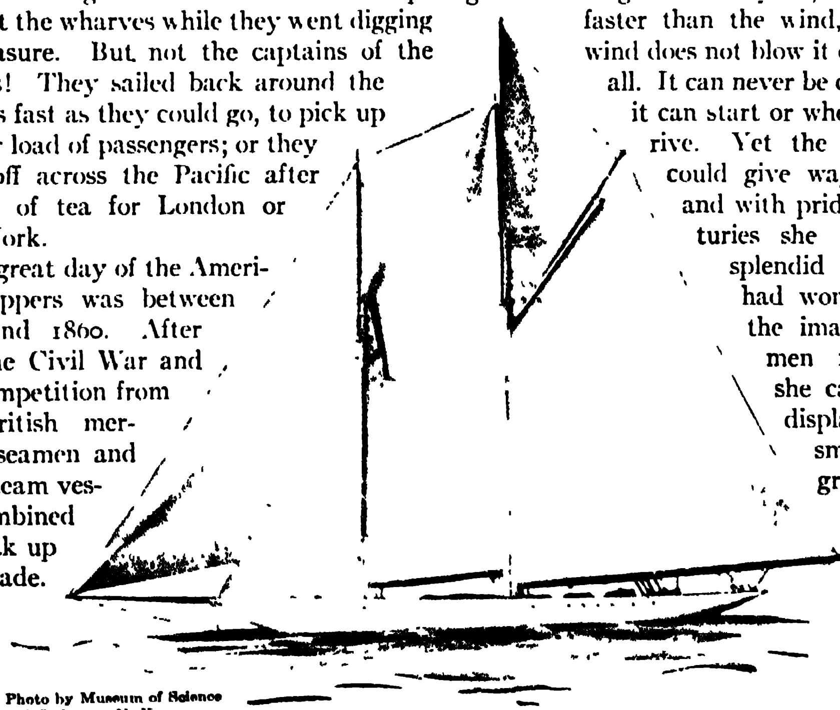


Photo by Museum of Science & Industry, N Y

This is the schooner yacht "Elena" that won the King Alphonso XII cup in the transatlantic race of 1929.

TRANSPORTATION

Reading Unit No. 6

WHEN WE PUT STEAM IN OUR CARTS

Note: For basic information not found on this page, consult the general Index, Vol. 15.

For statistical and current facts, consult the Richards Year Book Index.

Interesting Facts Explained

Cugnot and his steam wagon, 10–175

"Cap'n Dick" shows his steam carriage to London, 10-177

When the locomotive took to rails, 10-177-79

When Stephenson built a railroad line to carry American cotton to Manchester, 10-181

"Tom Thumb," the first American-built locomotive, 10-182-83

America's first railway accident, 10-183

A locomotive parade, 10-183

Things to Think About

How fast could some of the early steam carriages travel?

Why was the "Stourbridge Lion" of little use to its owners?

What caused the boiler blow out on the "Best Friend"?

Picture Hunt

What were the main features of the early locomotives? 10-177-79

What do we know about some of the famous early locomotives? 10–180-82

Related Material

How are logs loaded on railway cars? 9-253

How is food kept fresh on long train journeys? 1–409

How did James Watt put steam to work? 10-399-401

Why is the railroad business considered a natural monopoly? 7–543

Why is the outside track around a curve on a railroad banked? 1-310

How did the government help the Union Pacific Railroad Company? 7-278

What has been done to prevent the buckling of railroad tracks? 1-478

Leisure-time Activities

PROJECT NO. 1: Make a model of an early English steam locomotive, 10–180-81

PROJECT NO. 2: Make a model of "Tom Thumb," 10–182

Summary Statement

In principle, the locomotive works in about the same way as any other steam engine; it simply turns the wheels on the ground under a train, and so makes the train speed over the track.

[illegible]

This famous train with its great Diesel engine is slipping through Santa Susana Pass on its way from San Francisco to Los Angeles It was not until 1934 that Diesels were used in high speed passenger service in the United States But today we see more and more of them for they can pull more loaded cars more cheaply and more swiftly than steam engines can This recommends them in an era of high speed and high fuel

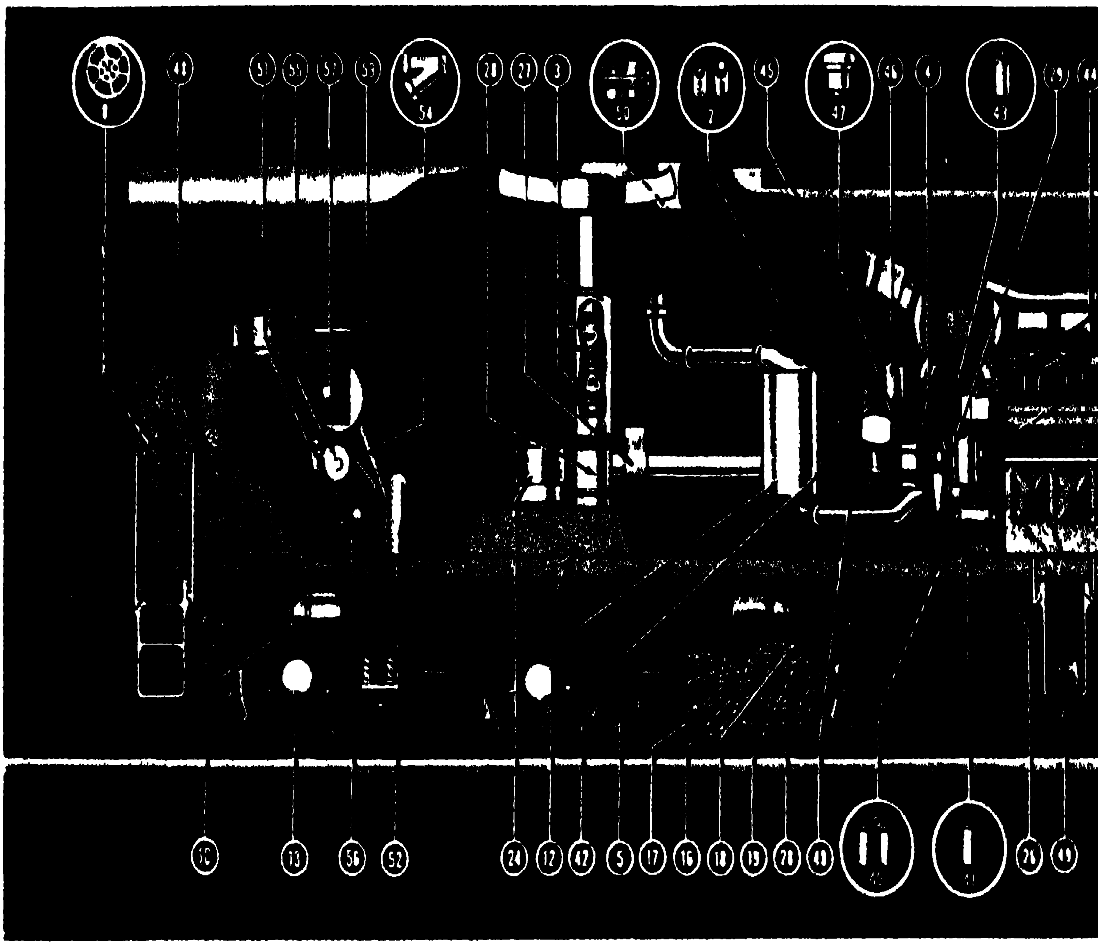


DIAGRAM OF A 2 000 HORSEPOWER DIESEL-ELECTRIC ROAD LOCOMOTIVE

1 Crankcase
2 Air compressor filler and level gauge
3 Radiator fan drive shaft
4 Flexible coupling (between engine and air compressor)
5 Fast coupling (between air compressor and radiator fan drive shaft)
6 Engine turning device (for turning engine during maintenance work)
7 Windshield wipers
8. Hand brake (inside cab)
9 Hinges and latches of cab doors
10 Air brake components
Reading five arrows top to bottom
Brake shoe slack adjusters
Brake shoe hangers
Brake cylinder
Brake cylinder push rod
Horizontal brake lever
11. Electrohydraulic engine speed and load governor
12 Truck center plate oil cups
13 Timken roller journal bearings
14 Fuel oil tank condensation drain valve
15 Drive gears (for exciter and auxiliary generators)
16 Refers to Traction motor armature bearing, commutator end (close)
17 Refers to Traction motor armature bearing, pinion end (far)
18 Traction motor suspension bearing
19 Refers to Traction motor suspension bearing
20 Traction motor gear case
21 Amplidine exciter
22 Auxiliary generators (near side, for traction motor blower motors)
23 Auxiliary generators (far side, for battery charging and control circuits)
24 Traction motor blowers (for air cooling of motors)
25 Motor generator set (for engine governor control circuit)
26. Motor driven fuel oil transfer, and governor lubri-

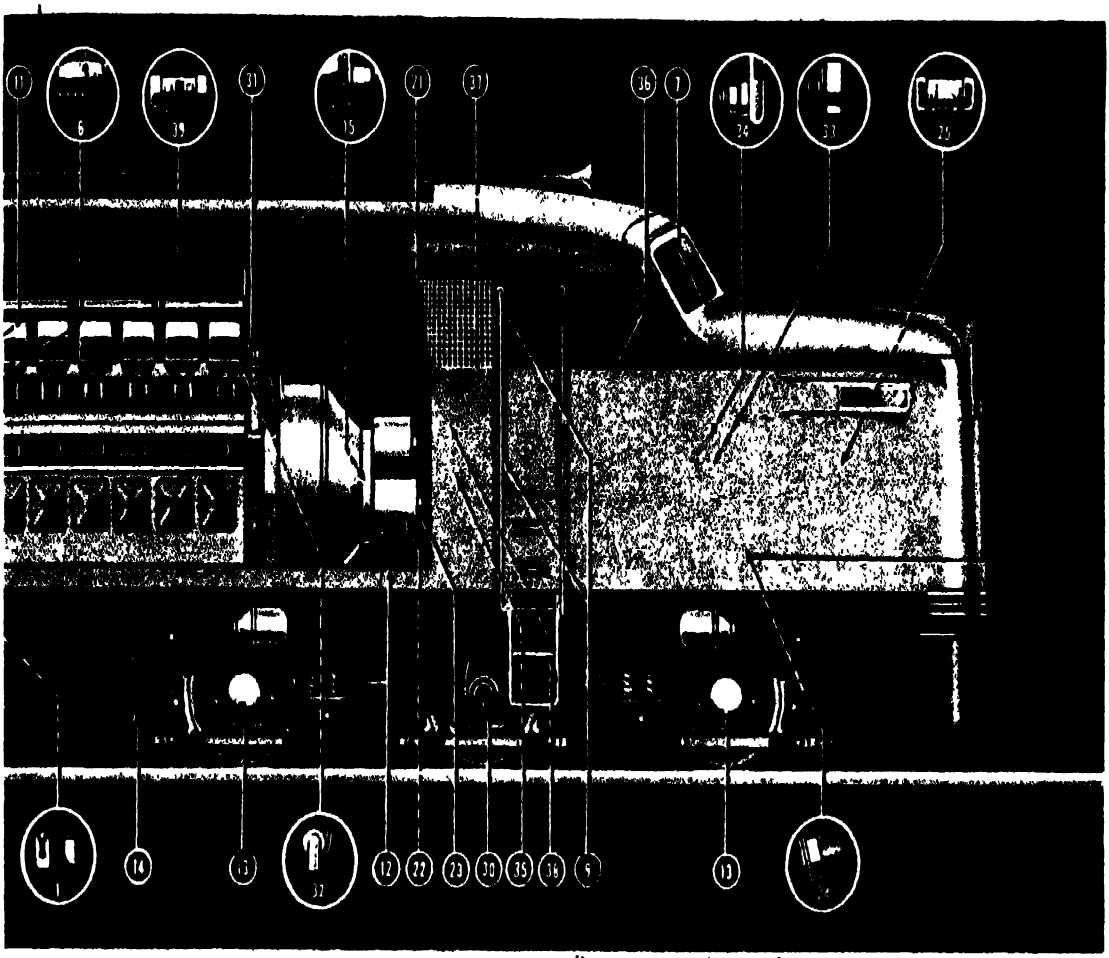


Diagram courtesy American Locomotive Company and General Electric

cating oil pumps
27. Eddy current clutch
28. Right angle drive gear box (for radiator fan drive shaft)
29. Engine governor hydraulic oil reservoir tank
30. Axle driven generator for train speed indicator, automatic transition control system and locomotive overspeed safety control system
31. Engine speed governor tachometer generator
32. Crankcase exhauster blower (for side behind tachometer generator)
33. Operating cab heaters, two (one each side)
34. Windshield defrosters, two (one each side)
35. Reverser (lower right side of control compartment central in cab)
36. Controller (throttle)
37. Electropneumatic contactors (in control compartment)
38. Transfer and dynamic braking switch (lower left side control compartment)
39. Dynamic braking grid blowers
40. Duplex fuel oil filter (far side)
41. Single element fuel discharge filter (far side)
42. Lubricating oil cooler
43. Obsolete. Turbosupercharger lube oil filter—no longer used
44. Electrohydraulic engine speed and load governor
45. Turbosupercharger air intake filter (panel type supersedes barrel type)
46. Air compressor intake filters (two)
47. Air compressor crankcase breather
48. Engine compartment air intake panel type filters
49. Air compressor intercooler
50. Air filter radiator shutter control
51. Fuel filter, steam generator
52. Water treater tank
53. Water by-pass control
54. Water strainer
55. Steam generator auxiliaries drive motor
56. Steam generator water pump
57. Steam generator forced draft blower

[Note: A diagram of a four-stroke cycle Diesel engine, together with a description of its operation will be found on page 276 of this volume.]

For heavy long-distance hauls Diesel locomotives are operated in units of two or three The train above has three They will furnish enough power to haul a heavily loaded freight train across high mountain passes, and can make their way around curves without trouble In a plant, stationary Diesel units may be multiplied This is a great advantage to the manufacturer, who is not obliged to rebuild a whole engine room in order to install a single, more powerful engine

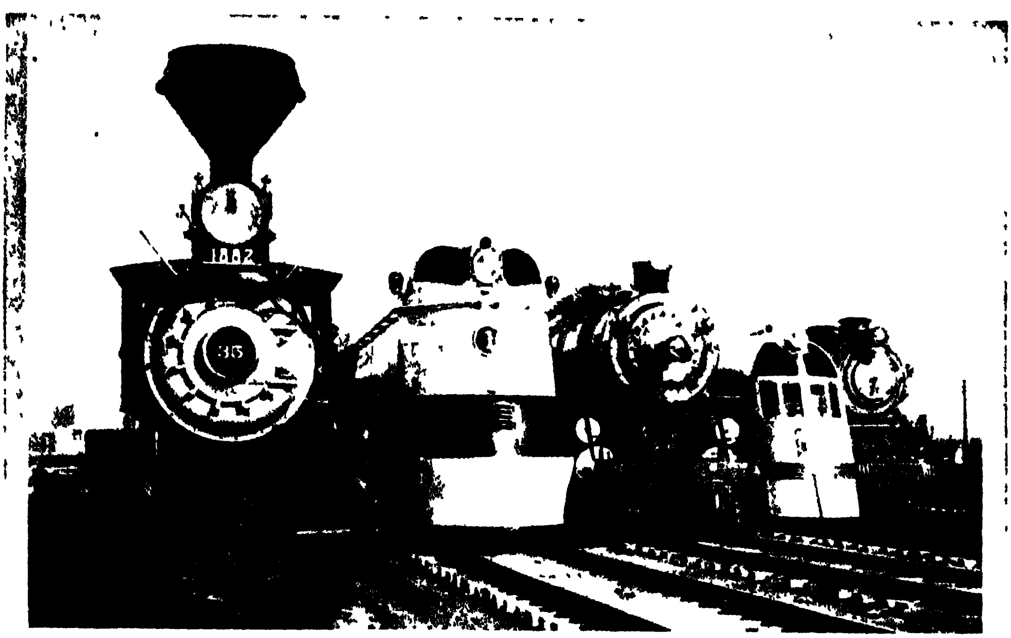
Moreover, a Diesel possesses other advantages as you may learn from our description of its operation on page 276 of this volume It is economical, has a long life, and is very dependable It is simple to operate, does not make itself a nuisance with smoke and ashes, needs only a small floor space, and does not have to have a large water supply Neither does it burn fuel when not in use, as a steam engine does

In a Diesel locomotive such as is diagramed on the preceding pages and in various other kinds of Diesel engines the Diesel's power is not applied directly to turn the wheels It is used to manufacture electricity and it is the electricity that drives the wheels, as well as lighting the train and serving various other purposes

Though advances are constantly being made Diesel power has not as yet been adapted to use in passenger automobiles and airplanes The engines are more expensive to build for automobiles than gasoline engines are, and are heavier for airplanes

The first Diesel engines were slow and very big and heavy Even after forty years of improvement the more powerful ones weighed 100 pounds per horsepower That is, a 100-horsepower engine weighed 10,000 pounds It was Charles Franklin Kettering who produced (1933) the modern light, high-speed, heavy-duty Diesel small enough to fit inside a railway car Today we have Diesels weighing as little as six pounds per horsepower, for use in trucks, buses, tractors, small boats, and as stationary engines for various purposes During the war Diesels installed in submarine chasers weighed as little as four pounds per horsepower The smallest Diesels develop five horsepower But giants of 7,000 horsepower are in common use

A new engine which came into general use after 1870 made it possible to build larger and faster ships and more economical ones Then bulky cargoes could be moved cheaply, and our modern world trade began The Diesel engine would seem to be in a fair way to introduce another such revolution in shipping on sea and land and perhaps in the air



Lined up beside a quaint old wood-burning engine of 1882 are four of the fastest trains in the United States to-day. Two of them, as you see, are stream-lined in construction, to gain greater speed.

WHEN WE PUT STEAM *in* OUR CARTS

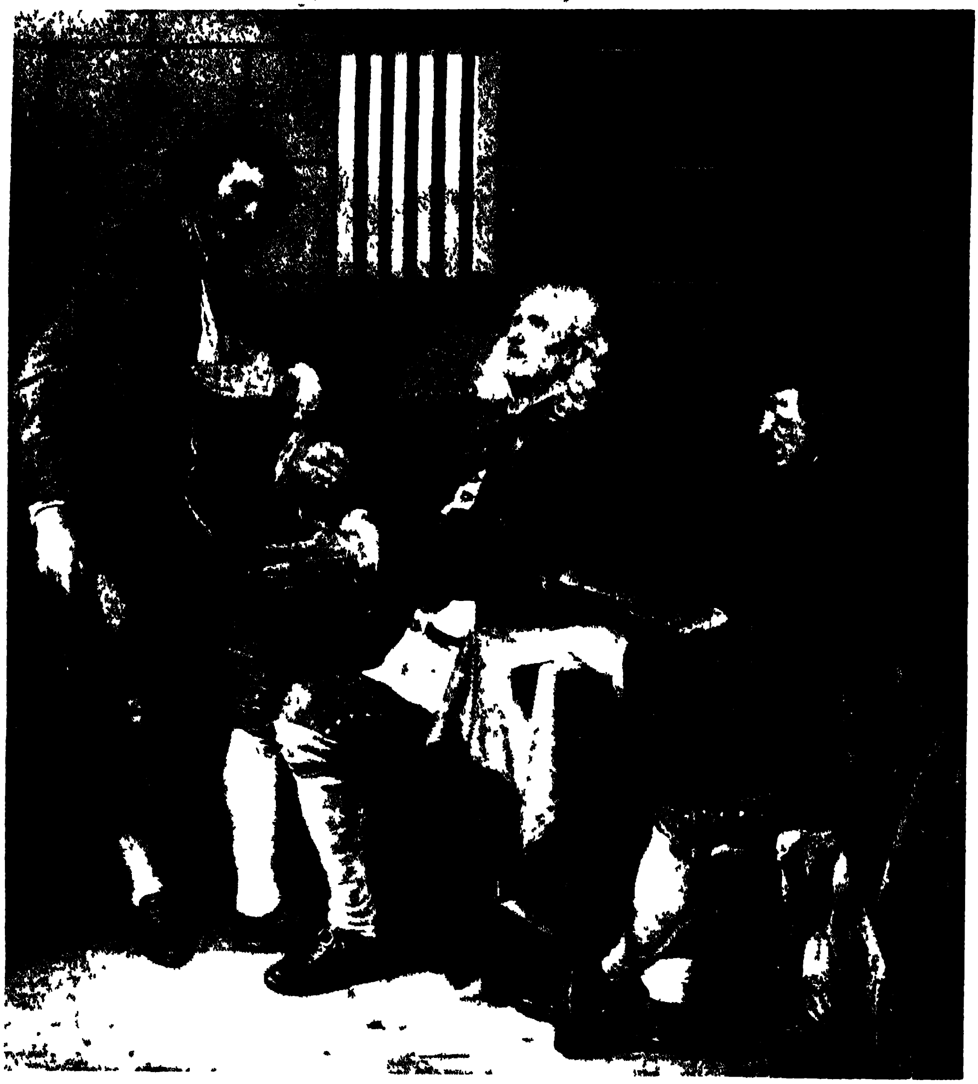
Up to a Hundred Years Ago, We Had Nothing but Muscle to Pull Our Wheels; Then We Put Steam behind Them

ONE day in the year 1770, when George III was beginning to have so much trouble with the people in America and when Louis XV was still sitting on the toppling throne of France, the men and women in Paris had a chance to see a queer thing on three wheels coming down a street in their city. There was no horse to pull it, and yet it puffed along at about three miles an hour. Most of the people merely laughed at it, of course, as they nearly always do at anything new. How could they dream that a thing of this kind was going to make the world over, and bring us all the railways hat now circle all the earth?

Behind a big copper boiler sat the pale 'nventor of this horseless wagon, Nicolas Joseph Cugnot (ku'nyō'). But who was this Cugnot, the people asked, and what was his outlandish machine for? And Cugnot was greatly disappointed. He had been working on his steam wagon for a year or more, and had the highest hopes of its first trial in public Bu it only got out of control and damaged some property. Cugnot was too poor to pay for the damage, so he was thrown into prison for it, and his dangerous machine was locked up where it could do no harm.

To-day Cugnot's machine is kept in a museum in Paris, as the very first steam locomotive in the world and the parent of all the power-driven locomotives we now have—the railway engine, the electric car, and even the automobile. But the people then must have mostly thought that poor Cugnot was some sort of lunatic.

For look at what had happened to old Solomon de Caus (dē kōs) over a century before. One day a visitor had come across him in the Paris asylum for the hopelessly insane. Looking out from behind his bars, Solomon kept saying, "I am not mad! I



Poor old Solomon de Caus was not the first man—nor the last—to be thought insane because he was ahead of his day. Here he is, in the French madhouse into which he was clapped because he had had the idea of the locomotive. Men would have had the invention two centuries earlier if they had been less stupid.

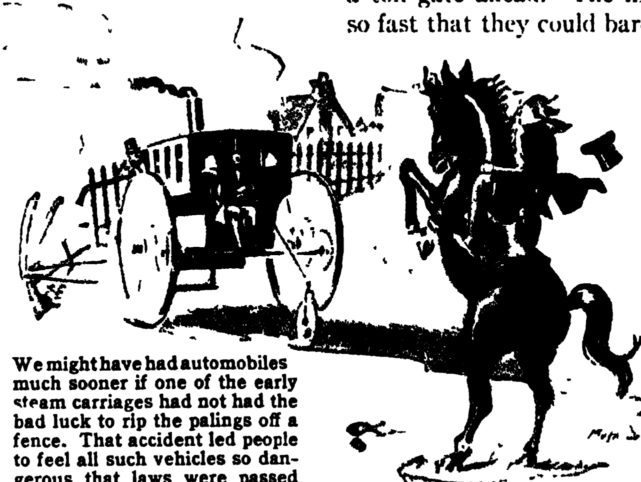
am not mad! I have made a discovery that will enrich the world!"

"And what is his discovery," inquired the visitor.

"Oh," replied the keeper, "that is only Solomon de Caus. He has a wild notion that he can make the steam from boiling water move ships and carriages. He came up to Paris to tell the King about it. But of course the Cardinal would not let him get at the King. And at last the Cardinal grew so tired of hearing him rave about his notion that he had to have Solomon locked up here."

By the time when Cugnot's carriage came to grief in Paris, a good many other people were thinking about steam vehicles. In England the great James Watt, whose stationary engines were already turning many a factory wheel, was taking out a patent for some sort of steam wagon. His manager, William Murdock, was making a small model of the locomotive.

Murdock wanted to keep his idea secret, and he tried his engine out at night on a road near his own home. It was only about a foot high, and the steam was made by the heat from a little spirit lamp. One dark night Murdock took his machine to a lonely path between the high hedges near the churchyard. The little three-wheeled thing was soon going along in fine style. In fact, it went so fast that it got away from Murdock; and the next thing he heard was some screams of fright. The vicar and his wife were walking quietly home in the dark when all at once this fiery thing came puffing and smoking along the path! In spite of all his prayers and sermons, the good vicar thought the power of evil must still be abroad in the land. Murdock soon ran up and quieted all fears, but this is the last we hear about the run of that little locomotive.



We might have had automobiles much sooner if one of the early steam carriages had not had the bad luck to rip the palings off a fence. That accident led people to feel all such vehicles so dangerous that laws were passed against them. As late as 1896 England had a law forbidding "any power propelled vehicle" to travel over a public highway at more than four miles an hour—and even then a man with a red flag had to go ahead of it! Many people in our own country will remember the protests of farmers and other drivers of horses when the automobile first invaded the country roads and caused countless runaways.

The First Real Locomotive

But a man who had studied under Murdock went a good deal farther. This was Richard Trevithick, or "Cap'n Dick," as he was called; he was born the year after Cugnot got into his trouble in Paris. He was a great big Cornishman, six feet two in height, and his mind was as good as his muscles. He built the first locomotive to carry passengers over a road in England, and also the first to draw a load on rails.

His first steam carriage was tried out on Christmas Eve of the very first year in the nineteenth century. That carriage got into trouble, but "Cap'n Dick" soon made another. This one went so well that he and his cousin, Andrew Vivian, decided to show it off in London. Over the terrible roads and hills of Cornwall, the thing went on its own steam to Plymouth, where it was loaded on a sailing ship for London. There it was much admired by great crowds of people.

One day as the engine was chugging along its way to Plymouth, Andrew Vivian spied a toll gate ahead. The machine was going so fast that they could barely stop it in time to keep it from crashing through the gate.

"What have us got to pay?" asked Vivian in his Cornish accent.

"Na—na -na —na!" stammered the gatekeeper, through his chattering teeth.

"What have us got to pay, I say!" cried Vivian, thinking the man was deaf.

"Na—na—*nothing*, Mr. Devil! Nothing to pay! Drive on!"

So Vivian and his cousin got up steam and flew on past leaving the gatekeeper with a story to tell for the rest of his life.

Now these first locomotives, as we see, were made to run on roads, and not on rails at all. Yet there had been "railways" of a sort in England for a long time. To haul coal from the mines to ships and barges, the miners had first laid down planks for the wagons. Then wooden rails had been nailed to the plank road, and the wagon wheels had been grooved to fit them. Still later the wooden rails were covered with scrap iron. All this made a much smoother road, and two horses could sometimes pull as much as twenty-four tons over it.

The Locomotive Takes to Rails

To railways such as these, around the Cornish mines, "Cap'n Dick" Trevithick

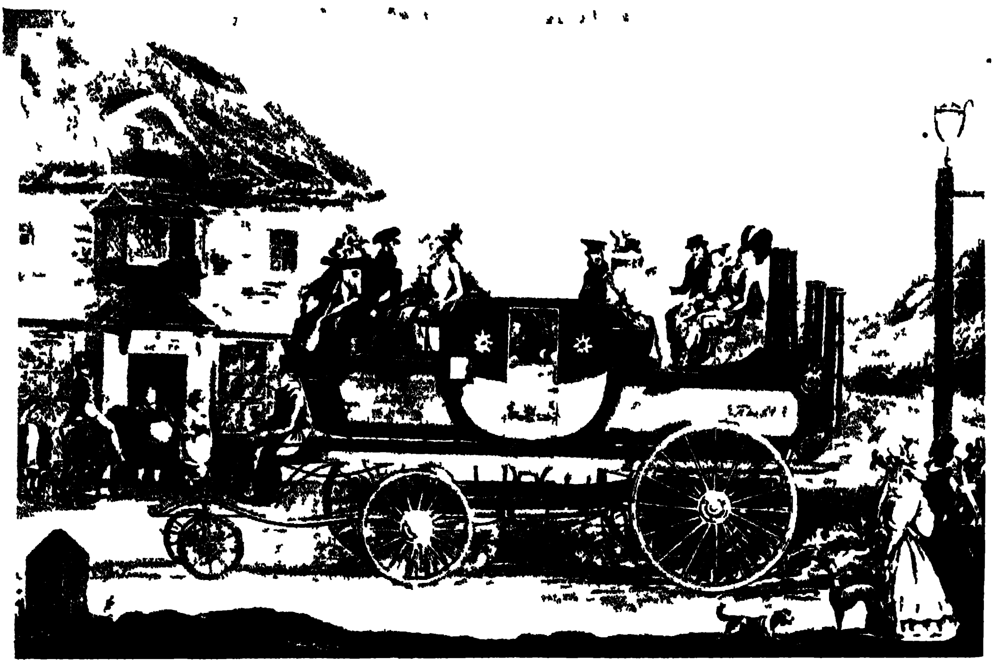


Photo by Science Museum London

In 1829 Goldsworthy Gurney traveled at fifteen miles an hour over the main highroad from London to Bath and back again in his ingenious steam carriage, shown above. It was the first long journey at steady speed ever made by a locomotive The driver sat in front, but the engine, which burned coke, was in the rear

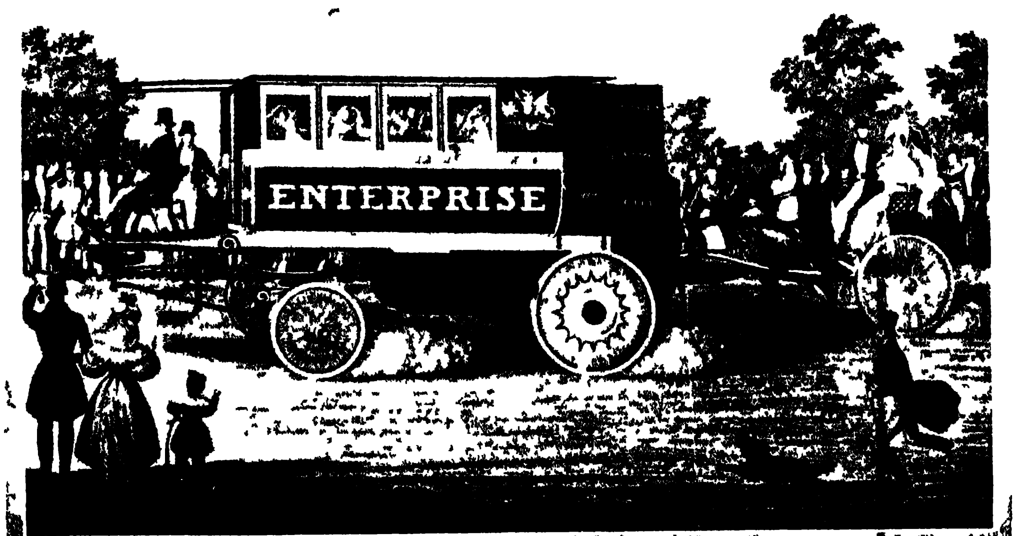


Photo by Science Museum London

When Walter Hancock let the "Enterprise" loose on the roads of England in 1833 he had already built two successful steam carriages The first began to run between London and Stratford in 1831.

had been used all his life. He was also used to hearing all sorts of bets as to what horses could do. "They ought to see what *my* horse can do," thought "Cap'n Dick" as he set to work on a new model. And a man named Humphrey, who bought the model, made a bet of a thousand guineas that it would haul ten tons of iron over a tram road nine miles long in Wales. Of course Humphrey won his bet. And though the machine went only five miles an hour, or slower than a horse, it was really the first railway locomotive that the world ever saw. Later it jumped the track, and "Cap'n Dick" lost interest in it. He sailed away to seek his fortune in South America.

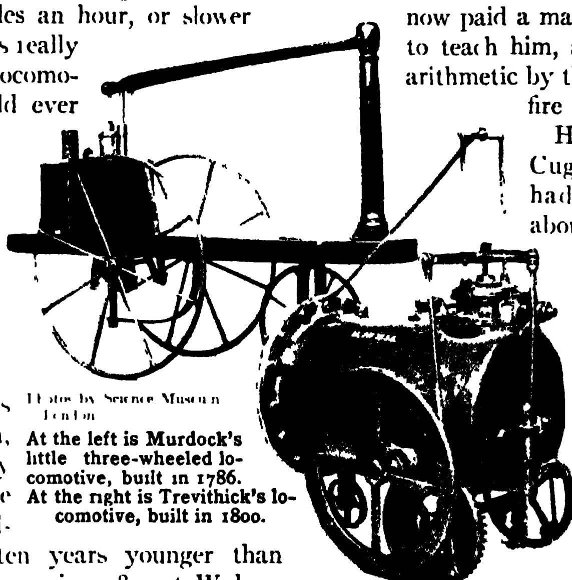


Photo by Science Museum London

At the left is Murdock's little three-wheeled locomotive, built in 1786. At the right is Trevithick's locomotive, built in 1800.

The next inventor was more persevering. That was George Stephenson, and more than any other man he is the "father of the railway." He was ten years younger than Trevithick, being born in 1781, at Wylam, in the coal country, way up near the Scottish border. His family was so poor that they all lived in one room, and at a very tender age the boys had to go to work. Before he was old enough for that, George had to look after the four younger children—and especially to keep them off the wooden railways that ran by their home. All day long the horses pulled the coal wagons down to the ships on the river Tyne. George used to set up water wheels in the brook near the house, and out of the clay around he was forever making models of the engines that he saw pumping water out of the mines or drawing up baskets of coal from the pits.

The Boyhood of George Stephenson

His own father was the fireman of a pumping engine, and at fourteen he was proud to get a shilling a day helping his father. One Saturday night about a year later, he was told that his pay would now be twelve shillings a week. "I am now a made man for life!" he shouted. Little did he dream what was ahead of him.

Yet he kept on working at his models of steam engines. All he could do was to make them like the ones he saw around him. To be sure, there were some books about steam engines now, but our strapping George, who could outbox anybody in the neighborhood, had never learned to read and write. He now paid a man threepence a week to teach him, and then he studied arithmetic by the light of his engine fire at night.

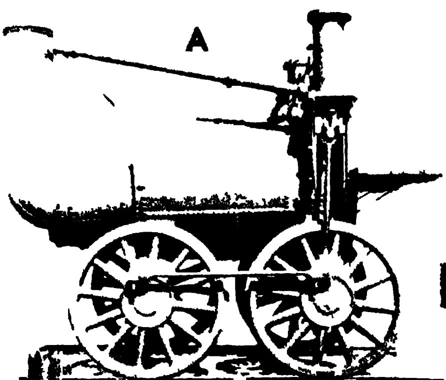
He read about what Cugnot and Murdock had been doing, and about the engines that Trevithick had built. There were now a good many other inventors in the field, and Stephenson found out about most of them. At Wylam he had seen a queer engine called "Puffing Billy," which used to pull eight or nine wagons down to the Tyne. And Stephenson kept plugging away at his own ideas, until before he was forty he had made a steam locomotive that was the wonder of everyone who saw it.

The First Railway in the World

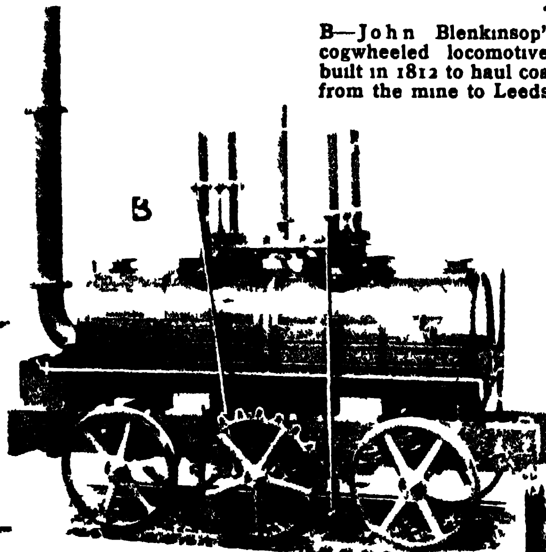
About this time he heard that some rich mine owners were planning a twelve-mile railway for horse-drawn wagons between two places called Stockton and Darlington. Seeing a chance to show what his engine could do, he went to a wealthy Quaker named Pease, who was interested in the line. "I am only the enginewright at Killingworth, that's what I am," he began; but he soon had Pease listening to every word he said. And when Pease saw what the engine was doing at Killingworth, he managed to persuade the other men to try one on the Stockton and Darlington line.

So on September 25, 1825, there was

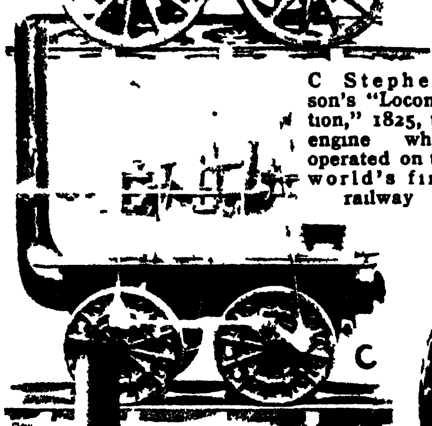
A—Hackworth's "Sans Pareil"—or "Without Equal" built in 1829, one of the competitors against Stephenson's "Rocket"



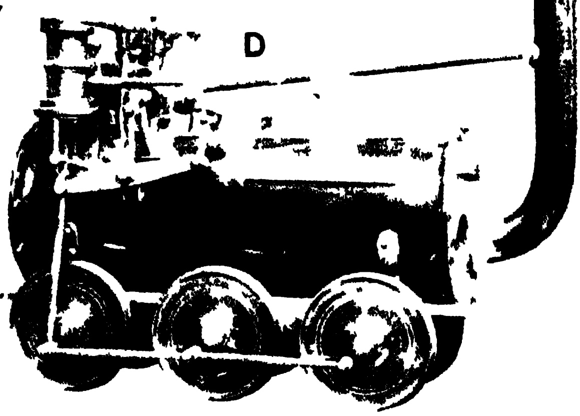
B—John Blenkinsop's cogwheeled locomotive, built in 1812 to haul coal from the mine to Leeds



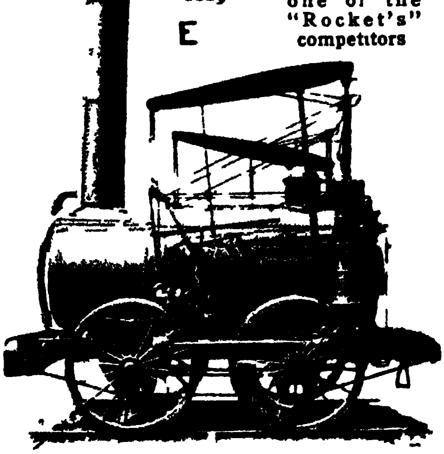
C Stephenson's "Locomotion," 1825, the engine which operated on the world's first railway



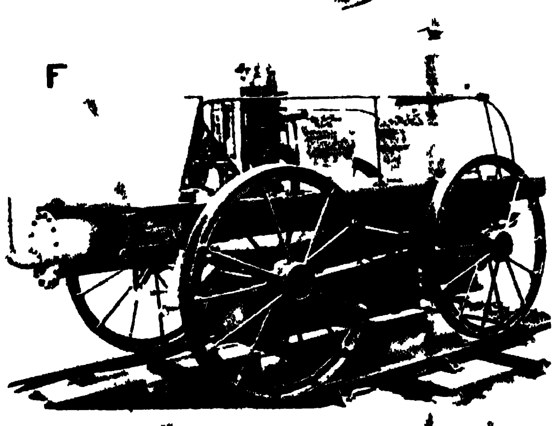
D—The "Royal George," the fashion in locomotives in 1827



E—The "Agenoria," an experiment of 1829



F The "Novelty," 1829, one of the "Rocket's" competitors



Photos by Science Museum London

opened the first railway in the world to carry passengers and goods. At the head of the procession out of Darlington rode a man on horseback bearing the company's flag. Behind him came Stephenson driving his engine, named "Locomotion." And behind this were six wagons full of coal and flour, a covered coach with the directors of the company, twenty-one wagons crammed with other passengers, and then six more filled with coal. As soon as Stephenson came to a down grade, he shouted to the horseman to get off the track, and gave the engine her head. The horseman and the runners were left far behind. And the train pulled into Stockton, as the papers of the day said, "in three hours and seven minutes, including stoppages, the distance being nearly twelve miles."

Ten Miles an Hour!

The Stockton and Darlington line was a success from the start. Still, when Stephenson built the more important line to bring American cotton from the ships at Liverpool to the mills at Manchester, he had a hard time persuading the directors to use engines instead of horses. When he told them he really believed he could make an engine pull a train at twenty miles an hour, some of them thought he was out of his head.

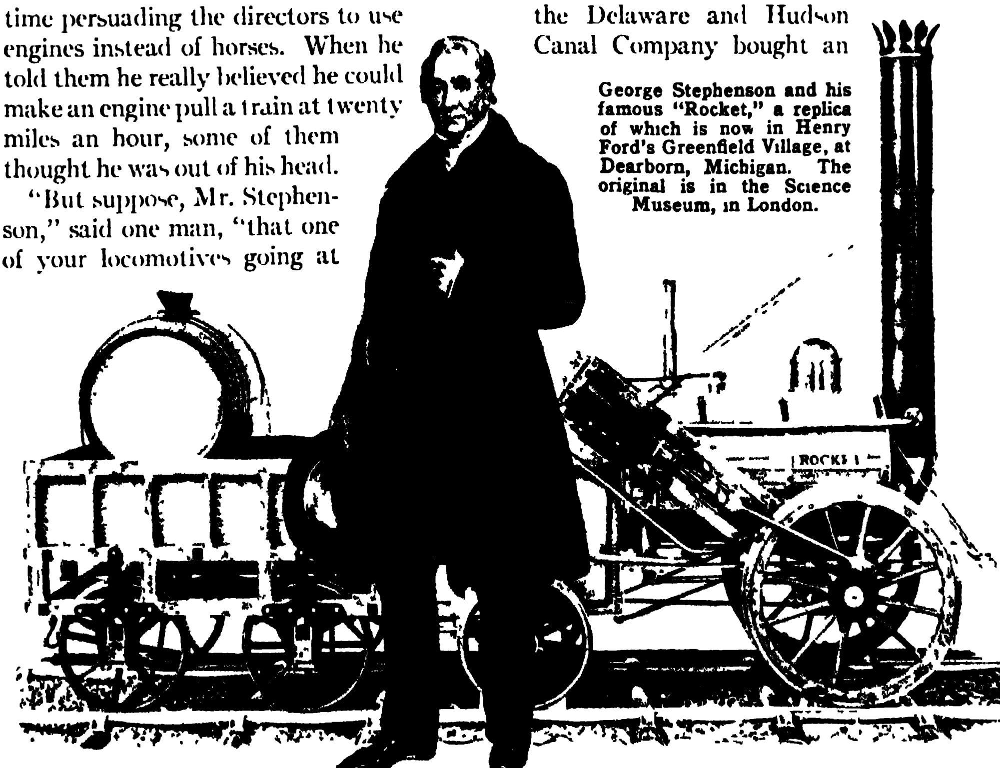
"But suppose, Mr. Stephenson," said one man, "that one of your locomotives going at the unbelievable speed of ten miles an hour should meet a cow!" Then he probably looked around as if to say, "*Now* I have him!"

But Stephenson only answered, in his northern accent, "It would be verra hard on the cow, sir."

The Locomotive Crosses the Sea

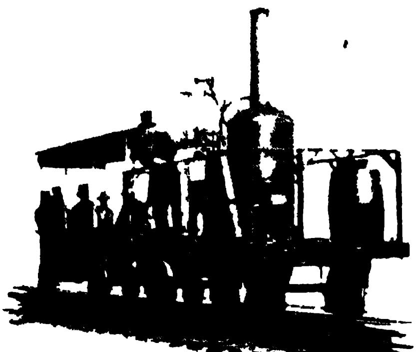
Even the experts were against Stephenson. They had far more education than he had, and they insisted that locomotives were out of the question. But Stephenson would not give in. Finally the directors offered a prize of £500 for any locomotive that would do the work. And Stephenson's "Rocket" won against two rivals. Part of the way it went as fast as twenty-nine miles an hour. So the "Rocket" and seven other engines built by Stephenson and his son Robert appeared in the procession that opened the line from Liverpool to Manchester in 1830. The line soon made its directors rich beyond their wildest dreams.

By this time the men of America had grown interested in steam locomotives. In 1829 the Delaware and Hudson Canal Company bought an



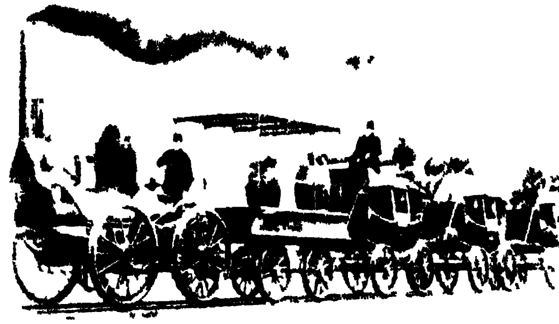
George Stephenson and his famous "Rocket," a replica of which is now in Henry Ford's Greenfield Village, at Dearborn, Michigan. The original is in the Science Museum, in London.

Photos by Science Museum, London



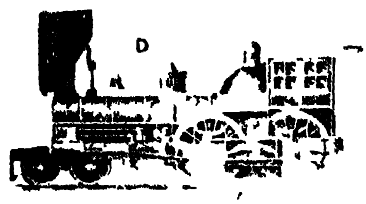
A

A—"Tom Thumb," 1830, the first locomotive built in the United States The company's directors are riding behind it



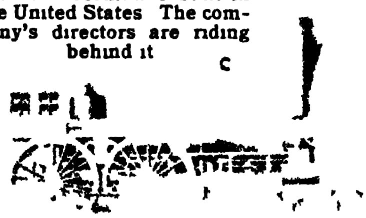
B

B The "De Witt Clinton" 1831, the first locomotive on the New York Central



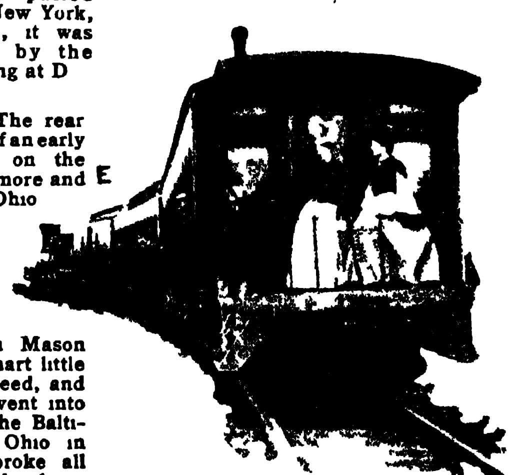
D

D When the first Empire State Express pulled out of New York, in 1851, it was hauled by the stripling at D



C

C By the time when this busy little gadfly was buzzing about from town to town the locomotive was no longer an experiment It had become a necessity And we may be sure that when people first saw this improved model of 1870 they thought it a marvel of efficiency.

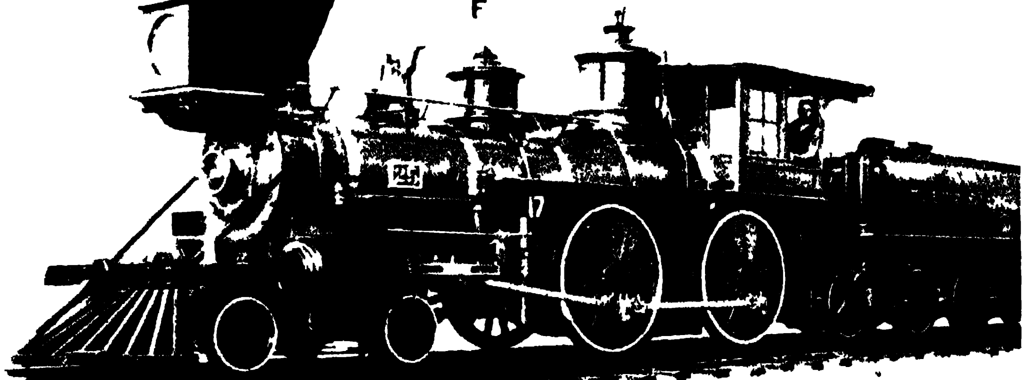


E

E—The rear end of an early train on the Baltimore and Ohio

F William Mason built this smart little affair for speed, and when she went into service on the Baltimore and Ohio in 1857 she broke all records all along the line

F



Photos by B & O and N Y Central Ry Co

English engine called the "Stourbridge Lion" to use on a track from their mines in Pennsylvania to the end of their canal. But the "Lion" proved to be too heavy for their track, and never was of much use to the company. You can see it now in the National Museum at Washington.

The First Railroad in America

Even earlier the legislature of Maryland had given the Baltimore and Ohio Company the right to build a railway thirteen miles long from Baltimore down the Patapsco River to Ellicott's Mills. At first only horses were used on the line. But in 1830 Peter Cooper built for this line the first steam locomotive ever made in America. It weighed one ton, and was named "Tom Thumb." The boiler was about the size of the one you may see on the kitchen range. All the same, Tom Thumb pulled a flat car all the way to Ellicott's Mills at eighteen miles an hour, with all the directors sitting up very straight and solemn on the car in their tall silk hats. They were the first passengers who ever traveled by steam on this side of the ocean. On the way back Tom Thumb had a race with a horse-drawn car. But a belt slipped, and Peter Cooper hurt his hand trying to put it back in place. So he had to shut off steam, and the horse won.

America's First Railway Accident

From the start, locomotives were used on the line from Charleston, South Carolina, to Savannah. In the same year that Tom Thumb lost his race in Maryland, the "Best Friend," built at West Point in New York, pulled the first whole train of cars to run in America. The driver wanted to end the run with a fine burst of speed, so he ordered the Negro fireman to pile on the pine knots. The Negro did so, and then thought he would sit on the safety valve to keep the steam from leaking. That was the end of the boiler!

Such were the beginnings of the locomotive. Everybody knows what the end is; but that is another story, and we are going to tell it in another place. There we shall show how the vast railways have grown up out of this invention and what they have done to make the world a different place to live in. From Cugnot's little three-wheel contrivance snorting at three miles an hour through the street in Paris we have come to the powerful giants that can roar across the continent in three or four days.

In principle, the steam locomotive works very much as any other steam engine does. In another story we have shown how the steam engine is made to turn all sorts of wheels. The locomotive simply turns the wheels on the ground under a train, and so makes the train speed over the track.

Many trains today are moved by diesel engines similar to steam engines though they have no boiler and burn oil. We associate diesel locomotives with the streamlined trains which, because of their design as well as their powerful engines, can travel over 100 miles an hour. Every year more and more diesels replace the old steam locomotives.

The Fair of the Iron Horse

In 1927 the Baltimore and Ohio held its "Fair of the Iron Horse" at Baltimore. In front of a grandstand seating twelve thousand people ran a circular track six thousand yards in length. Circling the track came a parade of locomotives, with little old "Tom Thumb" puffing bravely in the lead. After him came many another engine, showing all the marvelous improvements that have come in just one hundred years.

Canada sent some of her great engines—of the kind that made record time in hurling the special trains full of raw Japan silk from the ships at Vancouver to the mills in New York and New Jersey. The Great Western Railway of England sent its George V, a huge locomotive that could do a hundred miles an hour. The Baltimore and Ohio showed one of its own engines that could haul a thousand tons at seventy miles an hour. And there were many other engines—oil-burning engines and powerful electric locomotives among them. A whole century of locomotion passed in review. For it was just a century since George Stephenson had been talking himself hoarse to make some hard-headed business men catch a glimpse of the future and put money into his strange new hauling machine.

TRANSPORTATION

Reading Unit
No. 7

THE BELTS OF STEEL THAT BIND THE EARTH

Note: For basic information not found on this page, consult the general Index, Vol. 15.

For statistical and current facts, consult the Richards Year Book Index

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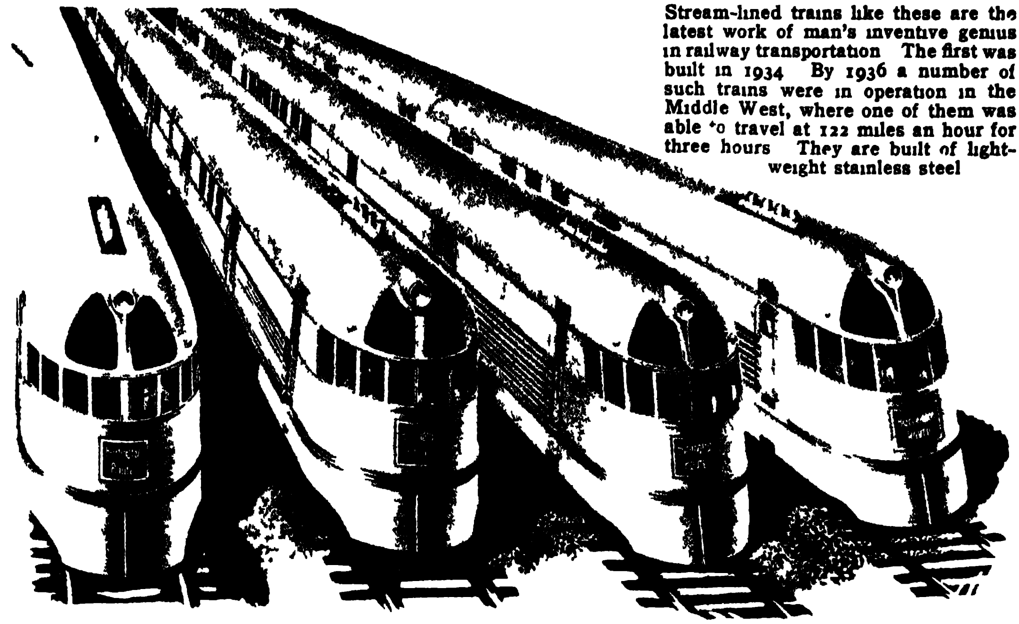
Summary Statement

The thunderous locomotive with its train of cars has ushered in all the marvels of our amazing Machine Age.



Stream-lined trains like these are the latest work of man's inventive genius in railway transportation. The first was built in 1934. By 1936 a number of such trains were in operation in the Middle West, where one of them was able to travel at 122 miles an hour for three hours. They are built of light-weight stainless steel.

The BELTS *of* STEEL THAT BIND *the* EARTH

Like Giant Spiders We Have Spun Our Webs of Railways around the Globe to Hold Men and Nations Together

DAY in day out, year in, year out the steel rails hum and sing with the hurry of the trains that are forever speeding back and forth over the face of the earth. "Hurry, hurry! Speed, speed!" shout the expresses as they flash by with their passengers and loads of precious goods. "We must make it! We must make it! Steady, steady, steady!" puff the freights that labor along with their great cargoes of wheat and bacon, of cotton and coal and automobiles and of thousands of other things that help to make up the life of civilized man in the twentieth century.

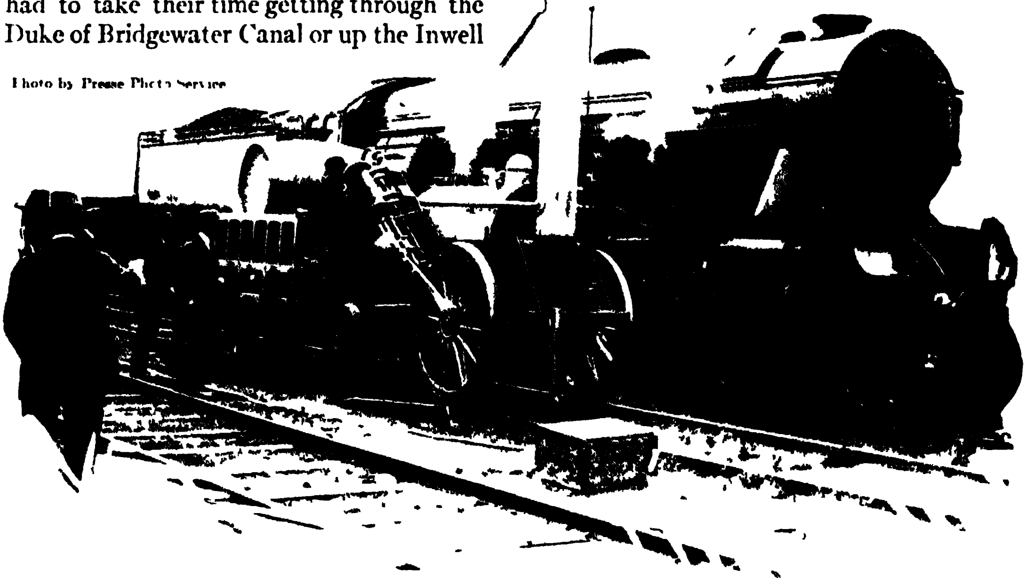
Five thousand miles across the great stretches of Siberia go the trains of the Trans-Siberian Railway. Up and up, along dizzy ledges, across daring bridges thrown over deep ravines, through tunnels blasted out of solid rock, climb the rails of the Peruvian Central, conquering the towering Andes at more than fifteen thousand feet above sea level. The rails have won the battle over the desert of Western Australia, and link the east and west coasts across the thirsty miles. The costly products of Central Africa find their way to the waiting ships along the coast over lines laid by men who were heroes. Those workmen had to fight back the crowding jungles, withstand the attacks of wild beasts, and battle the still more terrible onsets of tropical malaria. But slowly the earth's great wilds have been won. Steel binds Canada from coast to coast. And north and south, east and west, a vast network of rails has made the United States into one well-knit nation, when without them we might be more like a set of separate states and territories.

It was fitting that George Stephenson, the sturdy Britisher who made the first successful locomotive, should have been the engineer who laid the first real railroad. In the early eighteen hundreds the plantations in the Southern United States began to send very much larger shipments of cotton to be

made into cloth in the mills at Manchester in England The bales crossed the Atlantic in sailing ships to Liverpool, but then they had to take their time getting through the Duke of Bridgewater Canal or up the Inwell

This great British locomotive, a marvel of safety and speed, is standing beside its little old grandsire, George Stephenson's famous "Rocket" of over a century ago one of the first locomotives ever made.

Photo by Presse Photo Service



and Mersey rivers to the mills thirty miles away. And the finished goods had to find their way out in the same slow fashion. When the waterways froze in winter the hole flow of raw and finished cotton was dammed up, for sending the goods by wagon was very expensive At last the traffic got so dense that the waterways were glutted even when they were open.

How the First Railroad Was Built

That was Stephenson's chance. When he found that a rail line was planned, he used all his powers of persuasion and at last won the directors over to trying locomotives instead of horse-drawn wagons or cars driven by fixed engines.

To build the line was anything but child's play. In those days there were no giant steam shovels to take up two tons of earth at a bite and dump it out of the way. No engineer before had ever met a problem like the tunnel that Stephenson had to cut through two miles of sandstone in order to carry his line under a part of Liverpool. There was no pattern for the viaduct he built to carry his road on nine arches over the fifty-foot span above the Duke of Bridgewater Canal.

But Chat Moss gave him more to think about than any of these things It was a bottomless bog How was anyone to lay a railroad to carry heavy traffic over miles of such stuff? While he was struggling with all that mud, Stephenson heard that someone had compared him to Napoleon

"Don't speak to me about Napoleon," he said "Give me men, money, and materials, and I will do what Napoleon couldn t do—drive a railroad from Liverpool to Manchester over Chat Moss!"

He did it by sinking mattresses woven out of willow branches down into the bog and weighting them with stones until he got a firm foundation for his line. A long time afterwards the builders of the Canadian Pacific and the Trans-Siberian used the same device to conquer the swamps and tundras in their way

What England Thought of Railways

There was plenty of opposition to the railroads when they first started. There often is to anything new. A leading newspaper in England inquired bitterly, soon after the Liverpool-Manchester line was opened in 1830:

"Does anybody mean to say that decent people, passengers who would use their own

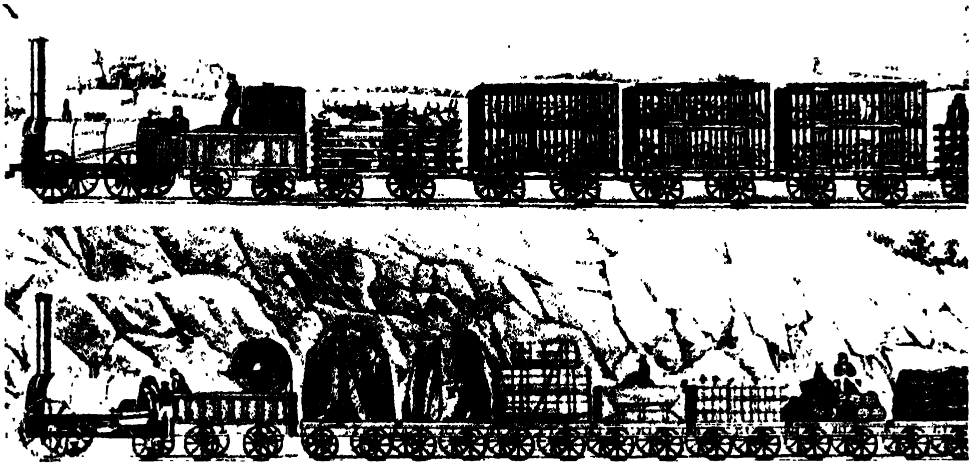


Photo by Science Museum, London

We may laugh to-day at these two queer little trains that snorted their way between Liverpool and Manchester a hundred years ago. But in 1834 they were a marvel of convenience and efficiency, and marked so great a stride in the progress of mankind that we may think of them as ushering in our modern age.

carriages and are accustomed to their own comforts, would consent to be hurried along through the air upon a railroad, from which, had a lazy schoolboy left a marble, or a wicked one a stone, they would be pitched off their perilous track, into the valley beneath; or is it to be imagined that women, who may like the fun of being whirled away on a party of pleasure for an hour to see a sight, would endure the fatigue, and misery, and danger, not only to themselves, but their children and families, of being dragged through the air at the rate of twenty miles an hour, all their lives being at the mercy of a tin pipe, or a copper boiler, or the accidental dropping of a pebble on the line of way?"

But to everyone's surprise passengers as well as goods were soon going by rail. In its first eighteen months the Liverpool and Manchester line carried more than half a million passengers. Why not, since the time by coach was four hours and the time by rail only an hour and a half? A newspaper of the time remarked that even when the trains were going at the terrific speed of twenty-five miles an hour, ladies and gentlemen were sitting in the cars and talking quite calmly!

The topmost picture shows how it is that an "iron horse" never stumbles off the track. That extension on the inner side of a locomotive's wheels presses against the inner side of the rails and keeps the locomotive from slipping either to right or left.

At the right are two pictures showing how a car is switched from one track to another. In the middle cut the wheels are going straight ahead on the track leading to the right, for they have no way of running on to the rails leading to the left. But in the lower cut the switch has been changed and the rails leading to the left-hand track have been shoved over to the right. Now the wheels, fitting down over the rails on the inner side as they do, have no choice but to keep ahead on the left-hand rail; so the locomotive turns to the left. The very short rails set just inside the main rails and running parallel to them help to hold the wheels in place, once the switch has been passed.

The influence of those great speeding dragons soon made itself felt. As railroads increased, the cost of merchandise went down, for freight rates could be made cheaper on railways than they had been by wagon. And land values went up. At first the owners through whose land the rails were laid had charged the most outlandish prices for the right of way; and many of them were quite honest in saying that a

railroad near them would damage their property.

But they soon learned better. The Duke of Bedford deserves to have his name go down in history because he actually paid back to the purchasers the sum of $750,000 when he found that he had overcharged the company for land he had sold them, since the railway had after all increased the value of his property instead of diminishing it.

In 1847 royalty itself put the seal of approval on the new-fashioned mode of travel. In that year Queen Victoria took a train instead of going from London to Windsor in her coach and six. And gradually the prophecy came true which George Stephenson had once made to his son Robert and another young engineer.

"Now, lads," he had said, "I will tell you that I think you will live to see the day, though I may not live so long, when railways will come to supersede all other methods of conveyance and in this country the mail coaches will go by railway and railroads will become the Great Highway of the King and all his subjects."

In England the first lines were built in order to give better transportation for goods and passengers that were all ready and waiting to be hauled. But in America the pioneer railroad builders had another purpose too. Theirs was the vision that prompted Edward Pease, a Quaker friend of Stephenson, to say, "Let the country but make the railways and the railways will make the country."

Our pioneers pushed their lines farther and farther out into the wilds, sure that along their two slender rails settlements and thriving industries would spring up. Bits of line strung out here and there were connected to make a larger whole. Gradually the Baltimore and Ohio added more and more track to that thirteen mile stretch between Baltimore and Ellicott's Mills over which the bustling little locomotive, "Tom Thumb," had raced with a horse and lost—in 1830, the very same year in which Stephenson's "Rocket" had opened the Manchester-Liverpool line. The road from Albany to Schenectady, over which the De Witt Clinton had puffed and panted for the first time in August, 1831, stretched itself out until there were rails the whole way from Albany to New York. In

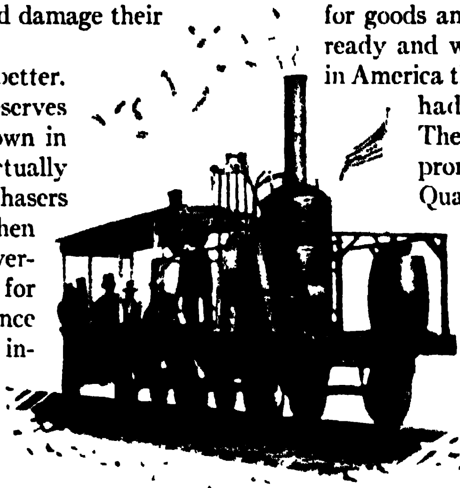


Photo by B & O Railway Co

On a great day in 1830 this strange little contrivance trundled along over the thirteen miles of track that lay between Baltimore and Ellicott's Mills, and drew behind it the little carriage to which you see it hitched. The gentlemen who are hardy enough to be taking the ride are the officials of the new Baltimore and Ohio railroad. They are the ones who have had the vision to buy the little locomotive, the first that was ever built in this country. It was aptly named Tom Thumb.

When the first railway track was laid in the United States, from Baltimore to Ellicott's Mills all of thirteen miles away, it was not the intention to use a locomotive upon it. One car was propelled by a horse on a treadmill; another car had a sail! But finally the managers fell back on old Dobbin, who drew the little car below back and forth once a day. This was the vehicle that vanquished Tom Thumb in the famous race.

Photo by B & O Railway Co.

In Europe railway passengers, by paying much or little, can purchasé simple or luxurious accommodations on a train; for tickets are sold for first, second, or third-class seats—and sometimes even for fourth class. The majority of people travel third class, in which the accommodations are about like those in our ordinary day coaches. First class corresponds a good deal to our Pullman or "parlor car" accommodations. Each railway carriage is labeled to show the kind of accommodations it contains.

Out of these amusing little railway coaches our luxurious modern trains have come. At the top is a first-class railway coach in use in England in 1840. To ride in that cramped little carriage was the most comfortable form of travel then known. In the center is a picture of a second-class carriage that traveled up and down England in 1837. And at the bottom of the page is a third-class English carriage in use in 1825.

Many European railway coaches of to-day are divided into compartments that run clear across the coach, as they do in the carriage at the left. There is a door at either side of each compartment. Sometimes the compartments open into a corridor running along one side of the coach.

Photo by Science Museum, London

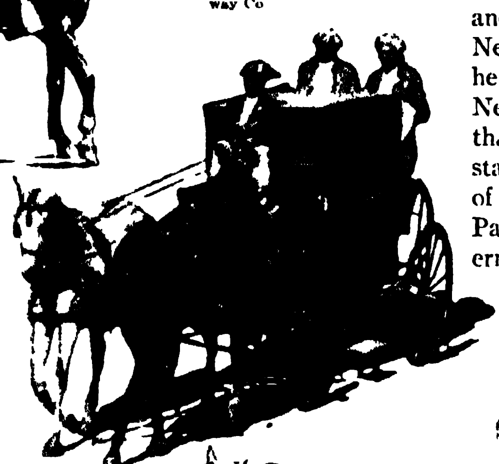
To anyone who has always ridden on the heavy trains that thunder over American railroads, the European trains at first seem small, or even toylike. But the traveler is soon charmed by the amazing smoothness of their motion and the speed they are able to make over their fine roadbeds. The small compartment, with its two rows of seats facing each other and running across the coach, has a secluded air. But the crowning touch comes at about four o'clock, when "tea baskets" are brought. One pays for a basket, consumes the cakes and steaming tea, and gives the basket and dishes to an attendant at the next station.

1830 there were twenty-three miles of track in the United States. Twenty years later nine thousand miles more had been added, though most of that mileage lay along the eastern seaboard, between the Atlantic and the Alleghenies.

But the day of the great railroad builders was still to come. It was the dream of all of them to bind the eastern to the western coast with bands of steel. For by water it was nineteen thousand miles from New York around Cape Horn to San Francisco; and to go by sea to Panama, then across the Isthmus by land, and up the coast by boat again, took four or five long weeks. The overland stage needed seventeen days to cover the distance from the Missouri River to California, though the "Pony Express," with hard riding and scarcely a pause for breath, took the mail through from St. Joseph, Missouri, to Placerville, California, in only eight. In 1853 surveys were made for a railroad from the Missouri to the Pacific, but things moved slowly in those days, and before anything could be done the Civil War came to interrupt all peaceful progress.

In the days of romance and discomfort, before the railroads came, people had to get about as best they could. At the left is the Pony Express, which carried the mail from St. Joseph, Missouri, to Placerville, California, in only eight days.

Photo by B & O. Railway Co



Before the day of railroads gentlemen often traveled in coaches like the one above, in which Henry Clay rode up to Washington.

Conestoga wagons, like the one below, jingled along with their loads of freight over the turnpike roads of Maryland and Pennsylvania.

Yet the dream was not forgotten. One of the men to cherish it was Cornelius Vanderbilt of New York. With almost no schooling he had started out in business for himself at the age of sixteen, when he began to run a ferry from New York City to Staten Island. While he was still a young man he had a string of steamers in the coast trade and a combination ship and overland transport route from New York to San Francisco by way of Lake Nicaragua. This competed successfully with the route already established across the Isthmus of Panama. His thriving shipping interests won Vanderbilt the nickname of "Commodore."

Then, about the time of the Civil War, having built up a fortune, Vanderbilt turned his attention to railroads. He bought up several lines and consolidated them into the New York Central. Finally he had a road all the way from New York to Chicago. By that time James J. Hill was starting out on his great career of building up the Canadian Pacific and the Great Northern; and E. H. Harriman, who became a member of the New York Stock Exchange at the youthful age of twenty-two, was working over the schemes that resulted in the first road from Chicago to the Pacific.

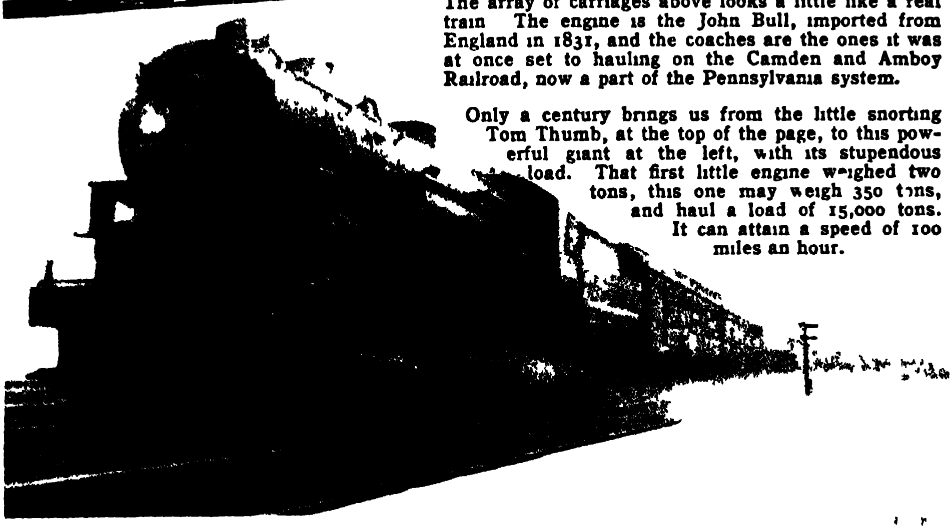
From Coast to Coast

On January 8, 1863 the first spadeful of earth was turned in the beginning of the long hard fight which was to fill the last gap in the line from coast to coast. The Central Pacific was to push from California over the Sierras and on east till it met the Union Pacific forces working westward from Omaha.

Above is the first railway train to run in New York State In 1831 this little locomotive, the De Witt Clinton, began to haul its strange procession of coaches from Schenectady to Albany.

For sixty-one years the sturdy little locomotive above, called the Atlantic, hauled its loads over the Baltimore and Ohio When it went into service in 1832 it drew double-decked coaches like these

The array of carriages above looks a little like a real train The engine is the John Bull, imported from England in 1831, and the coaches are the ones it was at once set to hauling on the Camden and Amboy Railroad, now a part of the Pennsylvania system.



Only a century brings us from the little snorting Tom Thumb, at the top of the page, to this powerful giant at the left, with its stupendous load. That first little engine weighed two tons, this one may weigh 350 tons, and haul a load of 15,000 tons. It can attain a speed of 100 miles an hour.

Photos by B & O Railway Co and Pennsylvania Railroad

Each company was eager to lay as many miles of the track as it could, in order to have the greatest possible amount of business along its route. And both companies were to have hardships in plenty.

The Central Pacific forces had to carry their line up seven thousand feet over the mountains. There, on cliffs so steep that the workmen had to be suspended by ropes against the face of the rocks, twenty-five hundred feet above roaring torrents, they chiseled a roadbed out of the solid granite. Saw-mills, water tanks, telegraph lines, and stations were all set up as the crew went along. The toiling thousands passed through the wilderness, and spun a railroad behind them. Sometimes they had to drive tunnels through solid masses of granite. Sometimes blizzards would swoop down upon them and cover them all in snow, and then a few thousand men would have to be put to work to dig things out again. Part of the way led through forests of trees whose trunks were four, five, or even eight feet thick, and it took three hundred men ten days to clean up one mile for the workers who laid the roadbed. Theodore P. Judah, called the "Railway Pathfinder," was the engineer who, after weeks spent in exploring the passes, had found out the best way for the line to get over the mountains. And Charles Crocker was the contractor who seemed to know just what to do to keep his Chinese workmen forever at the job until by the spring of 1868 the rails had gone east as far as Reno, and the worst of the difficulties were over.

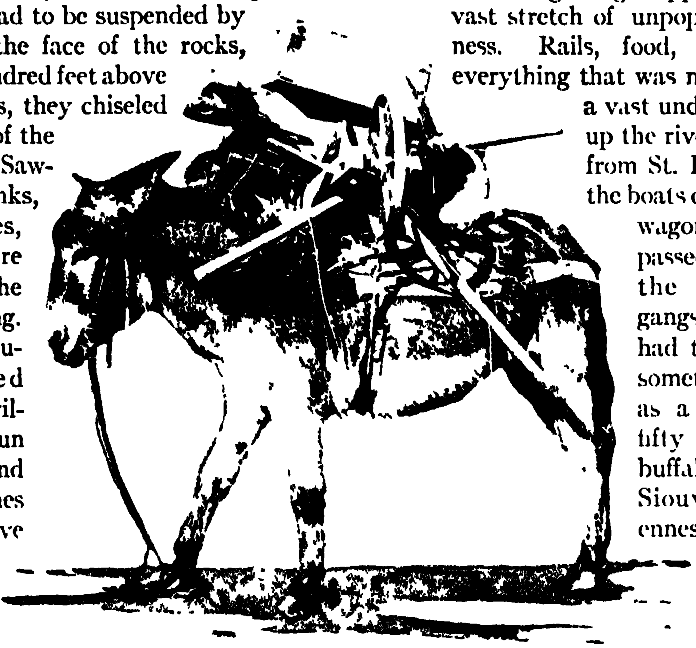


Photo by Underwood & Underwood

This donkey with the knowing look may well feel that he carries a railroad on his shoulders, for he and many more of his sure-footed kind have patiently fetched and carried when railroads were to be laid over high mountains and in other inaccessible places. This particular construction worker helped to build the road that climbs the 14,000 feet to the top of Pike's Peak, in Colorado.

Meanwhile the Irish workers on the Union Pacific were pushing along from the east, and they had their own troubles to encounter. Ground had been broken at Omaha on December 2, 1863, and there was level country across the plains for some seven hundred miles. The roadbed was easily made and the laying of the track went fast. The trouble was in getting supplies into that vast stretch of unpopulated wilderness. Rails, food, ties, lumber, everything that was needed in such a vast undertaking came up the rivers by steamer from St. Louis as far as the boats could go. Then wagons and ferries passed them on to the construction gangs. Water trains had to bring water sometimes as much as a hundred and fifty miles. In the buffalo country the Sioux and Cheyennes were so hostile that the surveyors did their work with an armed guard to protect them, and in Nebraska and Wyoming the track was laid inside a picket line of soldiers. Graders and track layers, tie men and station builders slept always under guard. The Indians were glad to kill or steal the stock and burn the cars and stations whenever they got a chance. And they seldom let a chance pass to take a white man's scalp! Frank J. North was a great hero in those days, for with his four companies of friendly Pawnees he outwitted the Sioux and Cheyennes again and again, and held them off while the work of civilization was pushed forward.

Workin' on the U Pay Ra-ailway:

The Irish workers were kept everlastingly at it by "General Jack" Casement, who was always telling them how much better

Photos by New York Central System

A luxurious transcontinental train is much like a fine hotel, as you may gather from the pictures on this page. Lounges, reading rooms, smoking rooms, observation and club cars, and expert service of many sorts help to make travelers comfortable. Some trains even boast a soda fountain. A barber shop for men, a beauty shop for women, a valet who will press and mend clothing, and highly trained stenographers and typists, all unite to give the passengers excellent service. Hurried travelers are often glad to save time by employing these attendants during a trip.

Photos by C B &Q. Ry. and the Pullman Co.

A modern Pullman train can offer the traveler complete privacy. A "drawing room" is like a comfortable bedroom with its own lavatory. It will accommodate a small family. "Bedrooms," "compartments," and "roomettes" all offer much the same facilities but are less roomy. A "section," shown above and at the left, is in the open part of the coach and consists of upper and lower berths which in the daytime become two sofas that face each other. You may have a table set up in your section and write or play cards, and you may have your meals served there if you prefer.

Photo by Union Pacific Railway

That was man's work—the building of the first transcontinental railroad. It was not only that the hardships of clearing the land were great, but also that miles of track had to be laid under fire from the Indians.

they were than Crocker's Chinese They sang all sorts of songs as they worked, one with this refrain:

> "Drill, my paddies, drill!
> Drill, you tarriers, drill!
> Oh, it's work all day,
> No sugar in your tay—
> Workin' on the U. Pay Ra-ailway!"

Over the Black Hills and into the Red Desert went the rails. In the summer of 1868 the Union Pacific had its share of mountain work when it crossed the Continental Divide at 7,164 feet above sea level. Now the men knew what those Chinamen in the Central Pacific gangs had had to go through. The two forces were getting nearer and nearer, and it was the Irish against the Chinese and the Chinese against the Irish, neck and neck for dear life. Casement's track layers were putting down three miles, four miles, five miles in a day. Crocker's Chinese laid seven miles. Casement's Irishmen laid seven and a half. Then the Central Pacific side made a bet of $10,000 that they would lay ten miles of track in a day. They did it, too, in April, 1869, when the two roads were just ten miles apart near Ogden, Utah. It was a record!

And so, after a little more than six years, the 690 miles from Sacramento and the 1086 miles from Omaha were finished There was a grand ceremony at Promontory, Utah, where the rails met. Crocker's Chinese laid one of the last two rails, while Casement's Irishmen laid the other. The last tie was of native mahogany, or laurel, and bound with silver. On a silver plate set in it were engraved the words, "The Last Tie on the Pacific Railroad, May 10, 1869," followed by the names of the railroad officers and directors. The spikes for the last rails were of gold from California and silver from Nevada. So the transcontinental line was opened, the settlement of the West was speeded up, the nation was knit closer together, and the stream of traffic around half the world was swerved in its course.

Steel Rails and Cross Ties

All this time many improvements were being made in railroading. The first tracks laid in the United States were of wooden rails covered with strap iron and fastened down to stone blocks. Sometimes bits of the iron would peel up from the wood and stick through the floor of the flimsy passenger cars. Soon came rails made all of iron, and white-oak ties. And then came steel rails, about 1865. They would last

In the Sky Lounge at the top of the page passengers on some of the fine trains may take the sun and watch the scenery In Pullman coaches like the one shown below they can spend the day and go to sleep at night Across each pair of seats a bed is made, and the passenger lies down with his head toward the engine Meanwhile a gigantic shelf has been let down from the side of the wall just above his head, and on it the upper berth has been made up Long curtains hang in front of each berth, and turn the section into two tiny bedrooms In European sleeping cars the beds are made up crosswise of the train Lately it has become possible for passengers on the finer trains to telephone home while the train is in motion

[illegible]rtesy of the Milw[illegible]ke[illegible] R[illegible]

Photo by L. B. Crocker Art Gallery

It is finished at last. The six hard years are over, and the last spike is being driven, at Promontory, Utah, in the railroad that is to bind the Atlantic to the Pacific with long lines of steel. Over those tracks will flow a steady and constantly growing stream of western emigration, the rising tide of a nation.

about fifteen times as long as the old ones of wrought iron.

Now a few years before that, George Pullman, a young business man of Chicago, had had to spend a night on the train between Buffalo and Westport. As he twisted and turned in his wretched bunk in the so-called "sleeping car," he tried to think of some way to make night travel less of a torture. The result was his "Pioneer," the first "palace car," which he persuaded directors of the Chicago and Alton to try. It was wider and higher than any coach then built, and was on eight-wheeled instead of four-wheeled trucks. The furnishings were very handsome, for it had cost $18,000.

The First Pullman Car

When it was done, the directors were invited to inspect it. They sat down in comfortable seats facing each other in pairs, and in a trice little tables were set up; china, linen, and silver were laid, and a delicious meal was served from a little kitchen at the end of the car. "Very fine," said the directors, "but where can one sleep here?" Pullman asked them to step into the day coach for five or ten minutes. When they came back there were the berths all comfortably made up with pillows, clean linen, and blankets. How fortunate for many a weary traveler that George Pullman had that hard night between Buffalo and Westport!

Westinghouse and His Air Brake

In the old days, each separate car had its own brakes. When the train came to a station, the brakemen would dash from one car to the other and wind up the brakes by hand until, with many a bump and jolt, the train came at last to a standstill, sometimes in front of the station, sometimes well down the track. One day when George Westinghouse, a young inventor of Schenectady, New York, was traveling home from Troy, he came to a place where a head-on collision between two freight trains had scattered goods and overturned cars over the whole line. One of the wrecking crew told Westinghouse that the accident had happened in broad daylight and that the engineers had seen each other for quite a distance. But they had not been able to stop their trains in time.

The accident set Westinghouse thinking. Surely there ought to be some better way

Photo by Pennsylvania Railroad Co

In this sightly dining room travelers may take their meals. The tiny kitchen is at one end of the coach.

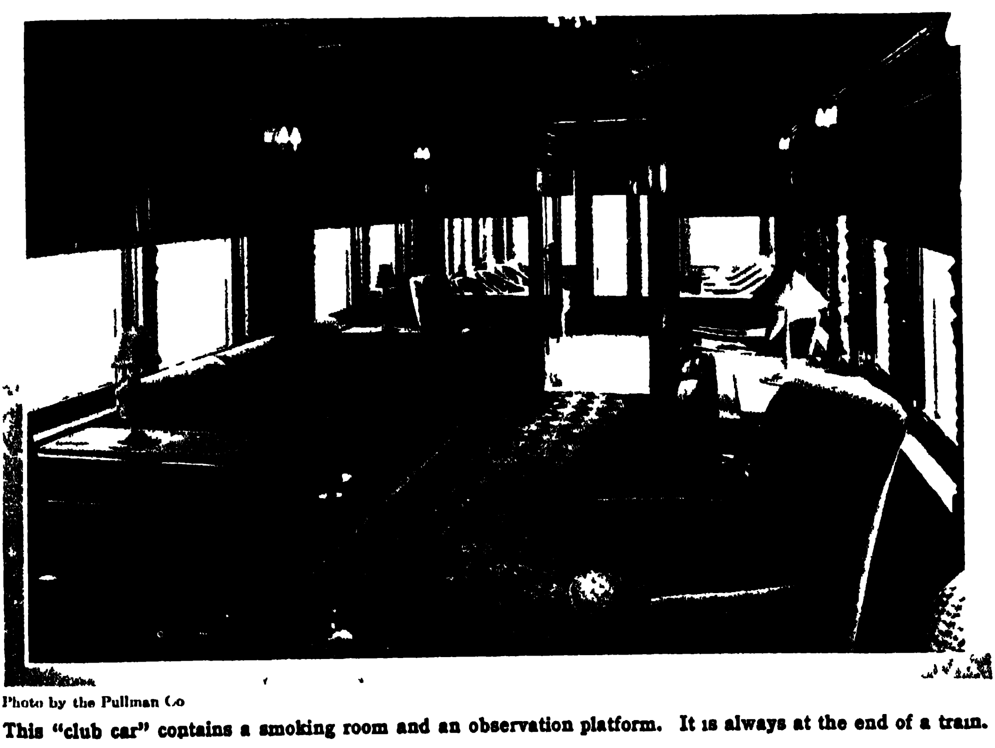
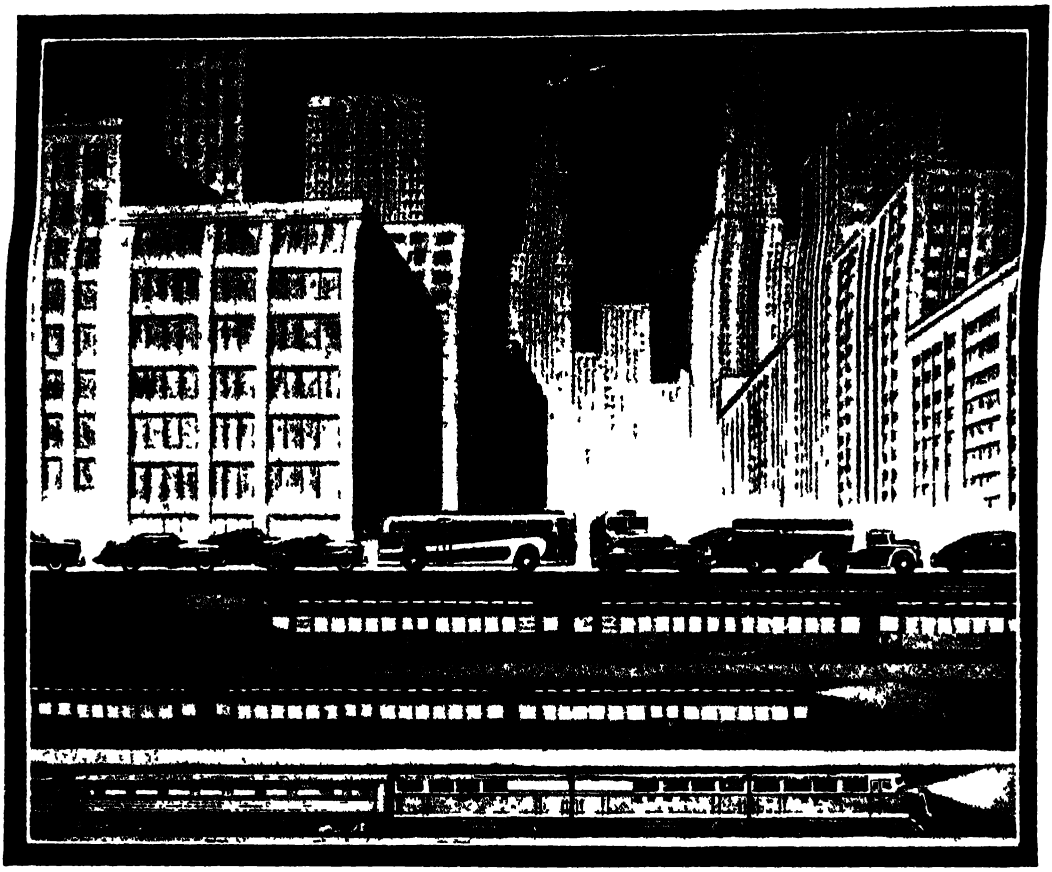


Photo by the Pullman Co

This "club car" contains a smoking room and an observation platform. It is always at the end of a train.



All these conveyances operate, one on top of another, in New York City. Trains and subways on three different levels shoot their passengers through tunnels underground to every part of the city. Buses and trucks and other motor vehicles speed through the crowded streets. And far above all this hurry and clatter, the airplanes come and go, and occasionally a giant dirigible floats lazily along. Yet all this welter of motion is only a part of what is going on, for up and down in those vast heaps of stone shoot thousands of elevators. Some cities have surface railways too, and trains elevated on tressles above the streets.

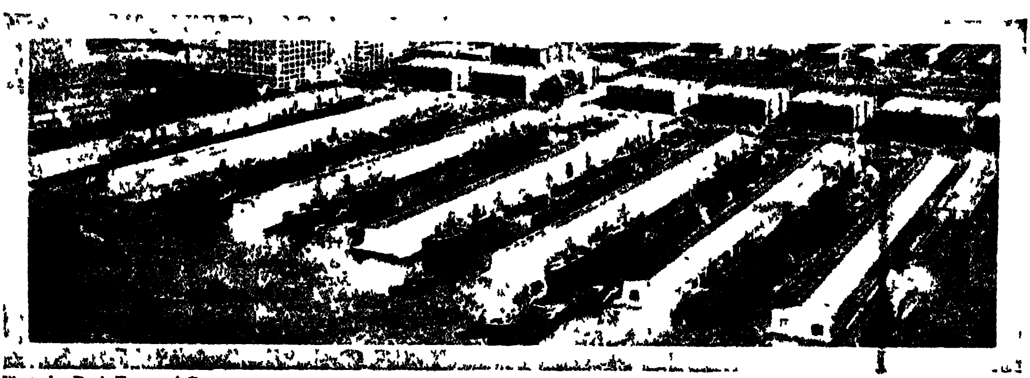
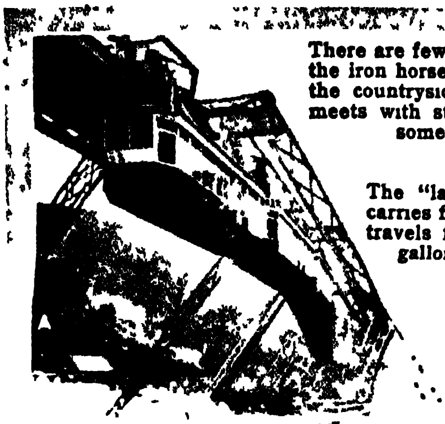


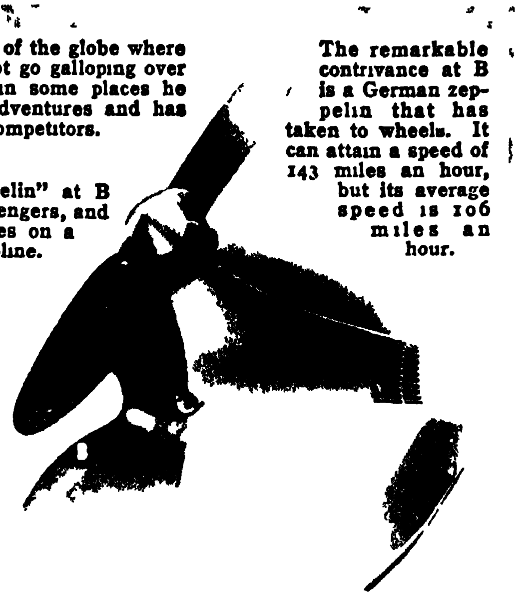
Photo by Bush Terminal Co

On these great docks freight is delivered in New York City ready for shipment to different parts of the country and different parts of the world. These are only a few of the great piers that line New York harbor. When a freight train reaches the Hudson River on the New Jersey side, its various cars are loaded on ferryboats that carry them to docks like the ones shown above. There, by a marvelous system, the goods will be unloaded and carried to warehouses or reloaded again for shipment hither and thither. Thousands of men find employment in the transfer, and millions of dollars worth ot goods are handled yearly.



There are few corners of the globe where the iron horse does not go galloping over the countryside, but in some places he meets with strange adventures and has some queer competitors.

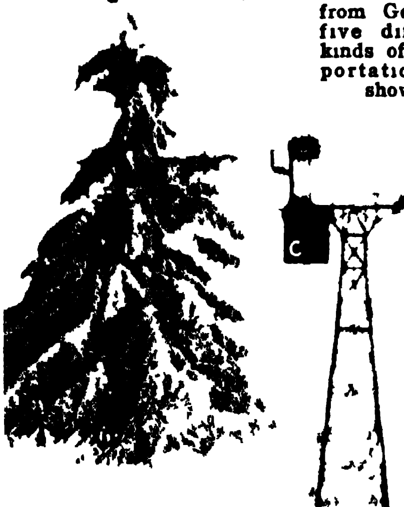
The "land zeppelin" at B carries fifty passengers, and travels four miles on a gallon of gasoline.

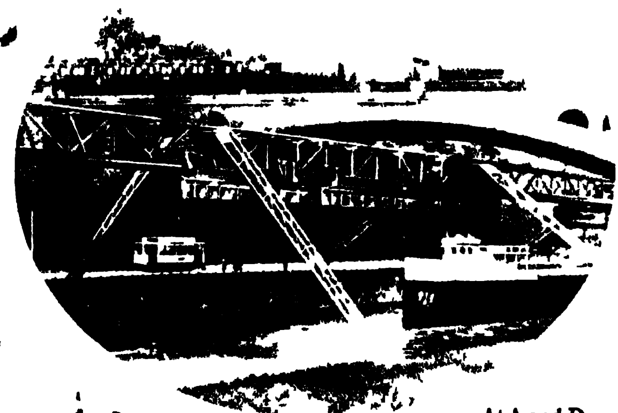


The remarkable contrivance at B is a German zeppelin that has taken to wheels. It can attain a speed of 143 miles an hour, but its average speed is 106 miles an hour.

C. A suspension road in Bavaria. The little cars are swung from above.

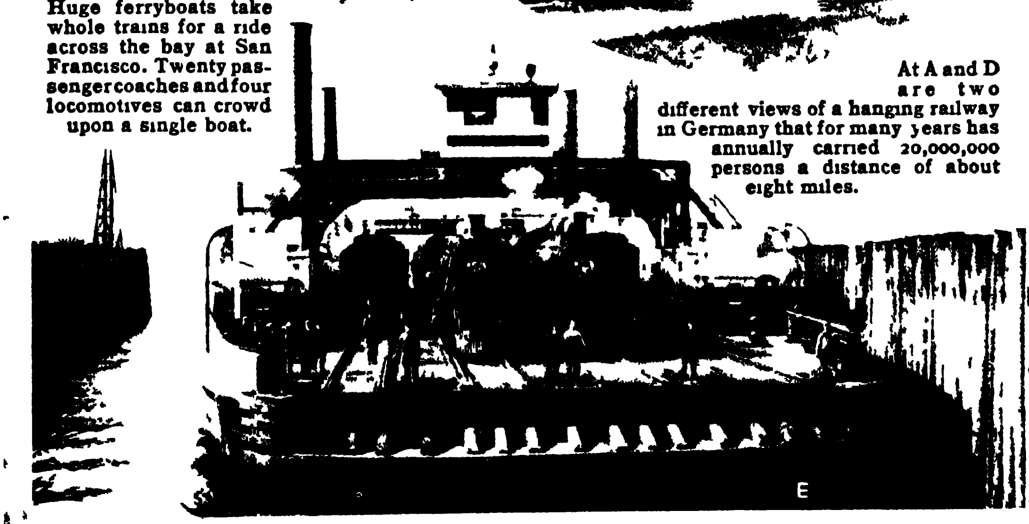
D. In this one photograph, which comes from Germany, five different kinds of transportation are shown.





Huge ferryboats take whole trains for a ride across the bay at San Francisco. Twenty passenger coaches and four locomotives can crowd upon a single boat.

At A and D are two different views of a hanging railway in Germany that for many years has annually carried 20,000,000 persons a distance of about eight miles.



Photos by Press Photo Service, Underwood & Underwood, Railways of Germany and San Francisco Chamber of Commerce.

to set those brakes! The proper way to do it would be to have the whole train controlled by some contrivance worked by the engineer. He was still puzzling over the problem when he happened to read that the drills for the Mont Cenis tunnel in Italy were worked by compressed air. If compressed air, piped three thousand feet into a mountain, could work the drills to make holes for blasting powder, why could not the same force be made to stop a train?

The answer was the Westinghouse air brake, patented in 1869, when its inventor was only twenty-three years old. It met the test. Controlled by the engineer in his cab, it stopped heavy trains in an amazingly short distance. No one can estimate the number of lives it has saved. Now all the railways of the world have their trains equipped with air brakes.

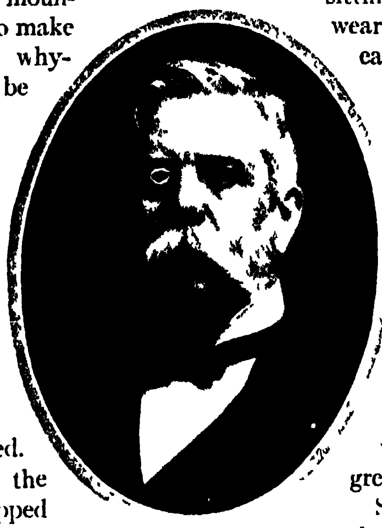


Photo by Westinghouse Air Brake Co

George Westinghouse, the man who saved countless lives by his invention of the air brake.

The railways of the world! There are stories to tell of them all—of how the Canadian Pacific was laid over the plains and peaks of the great Dominion; of how the Trans-Andean, between Valparaiso and Buenos Aires, went over the Andes by a tunnel two and a half miles long and more than ten thousand feet above sea level; of how Henry Flagler's road was dredged up out of the Florida Everglades and was sent across the Florida Keys and out over the sea to Key West. There are stories of other lines that have been driven across the Russian steppes and the Australian desert and over the Alps and into the jungle. Since George Stephenson started railroading in England, back in the first quarter of the last century, more than half a million miles of railroads have been laid down.

One of Our Greatest Servants

It is some seven thousand years since civilized man began to keep a record of his doings on earth. And compared with this whole span of history, how short is the era of the railroad. Yet how fast man has traveled up the path of progress in that short time, and how much of his world he has conquered and put to his own uses. The railroads played a part in giving you the roof over your head, the chair you are sitting on, the clothes you are wearing and the food you have eaten to-day. Certainly they had much to do with putting this book into your hands. Doubtless the wood pulp for the paper on which it is printed would to this hour have remained in some spruce forest of Canada if there had been no railway to fetch it out. The railway is not only the "Great Highway of the King and all his subjects." It is the very veins and arteries of the great world.

So when you next board one of those puffing, panting monsters, remember that the mightiest man of old, wise Socrates, brave Caesar, had not so powerful a slave at his command. A single train puts the equivalent of hundreds of servants at your disposal. It will carry you to corners of the land that only a few might visit a century ago. As you ride on its plush cushions you may know that all the wealth of kings could not purchase the traveler such comfort in the olden day. And how history has been changed because of these speeding giants. What deserts have been irrigated and filled with prosperous farmers; what oil wells have been opened to give their wealth to nations seized with a mania for speed; what wars have been fought for the possession of a distant corner of the earth that held some treasure quite unknown to men a century ago! Other eras will come, and swifter means of transportation, some of which we already see firmly established; but it has been the thunderous locomotive with its train of cars that has ushered in all the marvels of our amazing Machine Age.

TRANSPORTATION

Reading Unit No. 8

BORING THROUGH MOUNTAINS

Note: For basic information not found on this page, consult the general Index, Vol. 15.

For statistical and current facts, consult the Richards Year Book Index.

Interesting Facts Explained

How the famous Simplon tunnel was built, 10-203

How men defeated the mountain that made war on them, 10-204

Things we find inside a mountain, 10-204

Why the Egyptians and Romans made tunnels, 10-204

The longest railway tunnel in the United States, 10-206

Tunnels built under rivers, 10-207

Things to Think About

How is water carried underground?

How were the Holland Tubes built?

How many tunnels are there in Switzerland?

For what purposes do we need tunnels?

Which is the longest tunnel in the world?

Picture Hunt

How is the Holland Tunnel under the Hudson River ventilated? 10-202

How was the Posey Tube built? 10-205

Related Material

How was compressed air used when workers were digging tunnels under the Hudson? 1-460-62

How does the water from the Ashokan Reservoir reach New York City? 10-550

What part do tunnels play in irrigation systems? 10 539-44

Which tunnels have been built for the use of automobiles? 10-207

What causes the "caisson disease"? 1-461-62, 10-522, 524

Practical Applications

What are the two main ways of making tunnels to-day? 10-207

Why is our modern world honeycombed with tunnels? 10-204

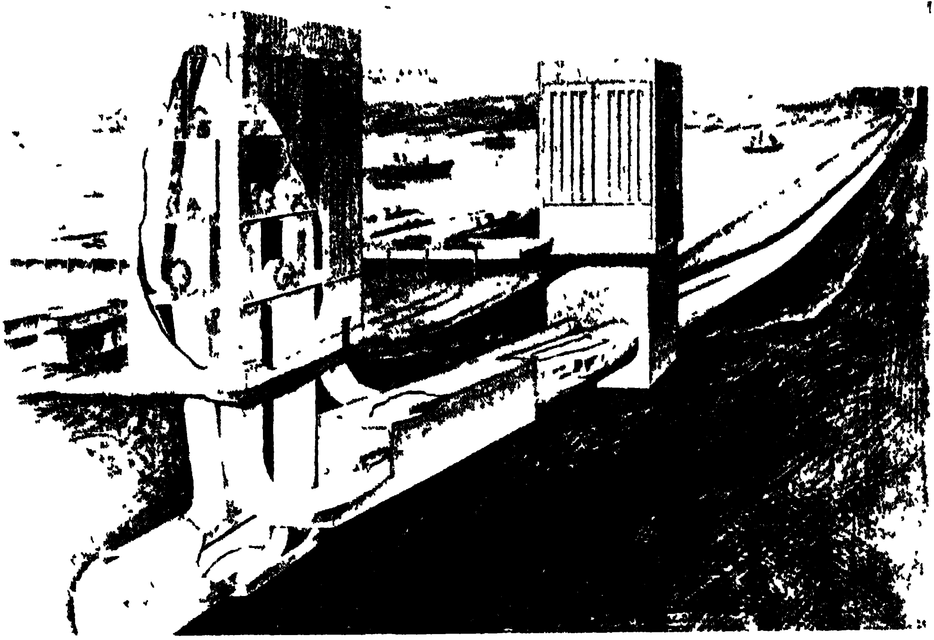
Leisure-time Activities

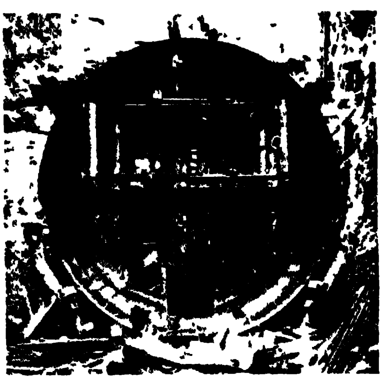
PROJECT NO. 1: Make a model of a mountain tunnel, 10-203, 206

PROJECT NO. 2: Build a model of an underwater tunnel, 10-205

Summary Statement

Our modern world is honeycombed with tunnels that are marvels of engineering skill and that are used for all kinds of purposes. Especially they convey aqueducts and railways underground.





Drawing and photos courtesy The Port of New York Authority

From the drawing at the top of the page you can get an idea of the way a great underwater tunnel is ventilated. Because the exhaust fumes of trucks and cars are poisonous, powerful fans suck fresh air through the tall towers down into ducts which run beneath the tunnel roadbed. When the air has circulated through the tunnel it is drawn off by exhaust fans.

In the middle of the page you see the great shield behind which the tunnel builders, called "sandhogs," work. At the left, workmen are assembling the shield, which is shown at the right going through a rock face ahead of the tunnel ribs. The two photographs at the bottom of the page show the shallow space above the tunnel ceiling where pipes and wiring will be laid, and the empty outer shell of a tunnel before the construction of either the ceiling or the automobile roadbed.

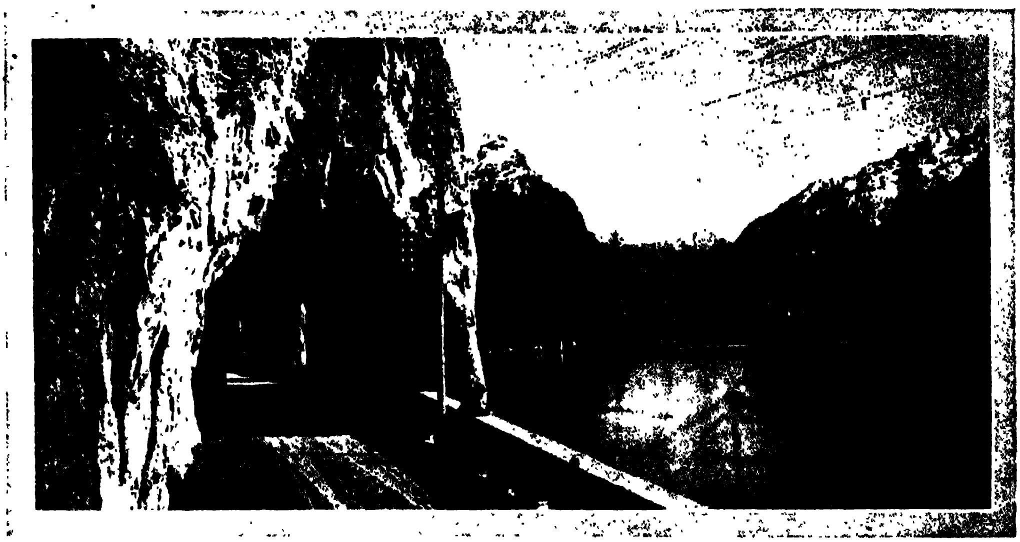


Photo by Swiss Federal Rys

The Axenstrasse, which skirts the lake of Lucerne in Switzerland, is surely one of the most beautiful roads in the world. And it is a marvel of engineering. Here it goes burrowing into the edge of a mountain, but still glimpsing the water between mighty pillars of rock. The little village of Fluelen beckons from the distance.

BORING *through the* MOUNTAINS

In Many a Place It Is Easier to Tunnel through the Ground than to Get over It. But How Do We Get Through?

IF YOU are going anywhere in a land like Switzerland you will find a mountain in your way, and if you are going far you will find a hundred of them. You must either go over the mountain, which is not always possible, or around it, which is often quite as hard —or you must go through it. If you are going through it, you will have to dig a tunnel.

Now it is hard enough merely to cut through the rock in a big mountain, but if that were all you had to do, the job would still be fairly simple. You may learn some of the other troubles from the story of the great Simplon tunnel in the Alps.

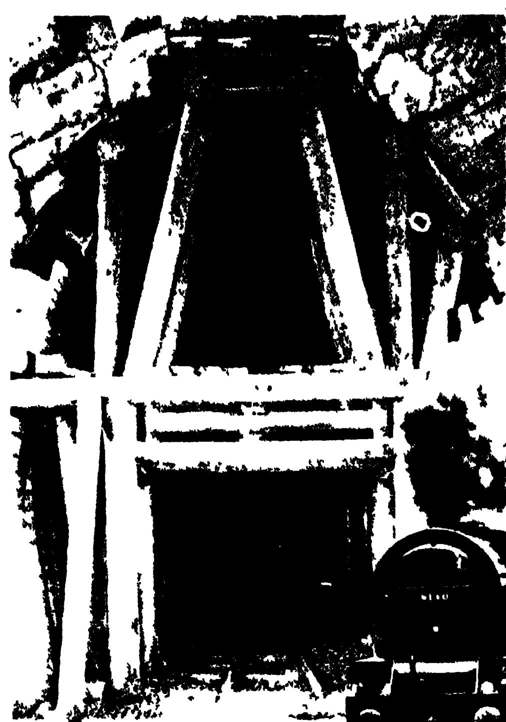
This tunnel starts in one side of a vast mountain in Switzerland and comes out on the other side in Italy. It runs for over twelve miles mainly through the solid rock, and in some places it has seven thousand feet of mountain above it. Only think of the weight on the roof and you will know what your first trouble would be—to keep your tunnel from caving in!

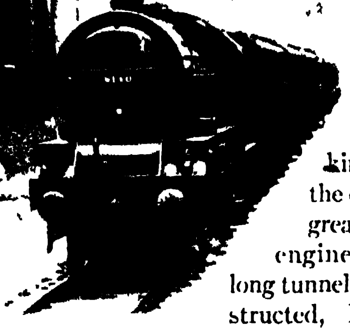
The tunnel was begun in 1898 and finished in 1905. The men started digging at both ends, and met in the middle eight years later. So they had to know exactly where they were going—and a tunnel cannot always go straight either.

Of course they had machines to do the digging—drills to cut into the rock, explosives to blast it away, and cars to carry it out of the hole. In this way they could cut in about thirty-five feet deeper every day, though a day meant twenty-four hours, for the work never paused.

As soon as they had gone a little way into the mountain, they had to have vast quantities of fresh air pumped in for them to breathe. For not only does the air get very stale in a deep hole in the ground, but the earth itself may give out gases that are poisonous. No one can live in a long tunnel unless a great deal of air is sent in from outside. So the farther the men cut into the rock, the more fresh air had to be forced in by the great pumps out of doors. There were ten thousand men who had to breathe inside.

On the Italian side they had not gone very far before they struck a soft spot — of loose earth instead of rock. They would have loved the rock far better. Easy enough to cut into soft earth, but what would keep the hole there? The earth above rushed down to fill the hole, with all the weight of the mountain to push it. The heaviest timbers that the men could put up were crushed like so many matches, and their great steel beams were bent and twisted out of shape. And not only did the roof fall in; if they managed to prop that up, the very floor was forced up by the enormous pressure that came down on both sides The whole mountain had gone to war with the men who were bent on piercing its heart. But finally the men won. With steel and concrete they managed to keep the passage open, on into the rock beyond.





Photos by Deutsches Museum & I M. & S Ry

Above is a model of the great Simplon tunnel, and at the right is one of the trains which roar back and forth through it day after day.

Things We Find inside a Mountain

But then they struck a vast spring of icy water. It was like a little river flowing in to fill up the tunnel—at more than ten thousand gallons every minute. So all work had to stop for some six months, until enough pumps had been installed to take care of the river.

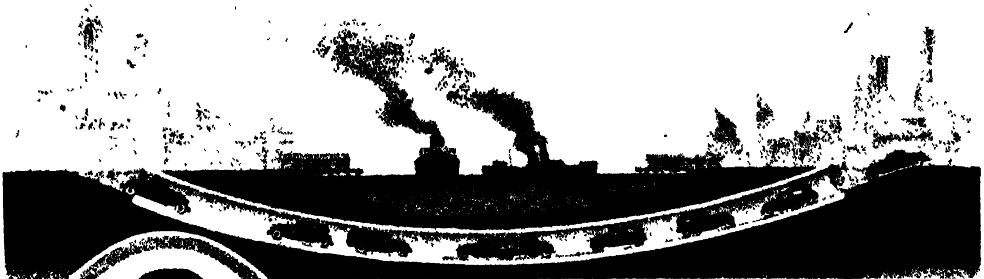
Farther on it grew very warm inside the mountain. The rock was hot and jets of steaming water would spurt out of it. So here a stream of cold water had to be pumped in to spray the rock.

These are some of the troubles in digging a great tunnel. Through them all the work went on, at vast expense, until the Simplon was completed and became the greatest highway through a mountain in the world.

Now men had long been digging tunnels before they learned how to cut a great one like the Simplon The first man who ever hollowed out a cave to sleep in was beginning the first of all tunnels. By the time of the Egyptian builders certain deep tunnels were being cut into the stone, mainly to bury the kings; and in the days of the great Roman engineers some long tunnels were constructed, largely to carry water But of course the modern tunnel, dug with machines and dynamite, far surpasses anything from ancient times.

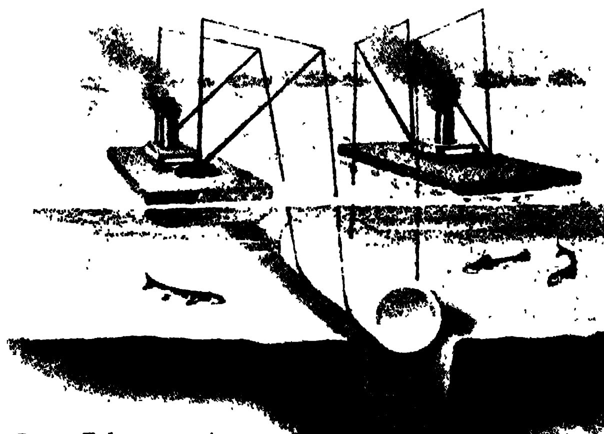
We need tunnels for many things that are done better under the ground than on the surface—for getting through great hills and mountains, for going under rivers, for bringing water to our towns, for running subways and sewers and electric wires through our cities, and above all for building railroads in all hilly countries. Our modern world is honeycombed with tunnels for all these and other purposes, and they are often remarkable works of science.

Thus in Switzerland there are many other tunnels besides the great Simplon. There is the St Gotthard (säN gô'tär'), over nine miles long; and the Loetschberg (lûtsh'bĕrg),



Above is a cross section of the Posey Tube under the Inner Harbor of San Francisco, between the cities of Alameda and Oakland. The tube was named after its chief engineer, and well he deserved the honor for the boldness and skill of his planning and direction.

Above is one end of a segment, or section, of the Posey Tube; it is made of reinforced concrete.



The Posey Tube was not a tunnel at all while it was being built. The enormous segments of tube were cast on shore and then towed out by tugboats, as is shown at the right. Meanwhile a great trench had been dredged out, into which each section was neatly fitted, as above.

And now that the tube is finished, a long line of cars goes in and out of it all day long, binding the "sister cities" together across, or rather under, the water.

Photos by George A. Posey

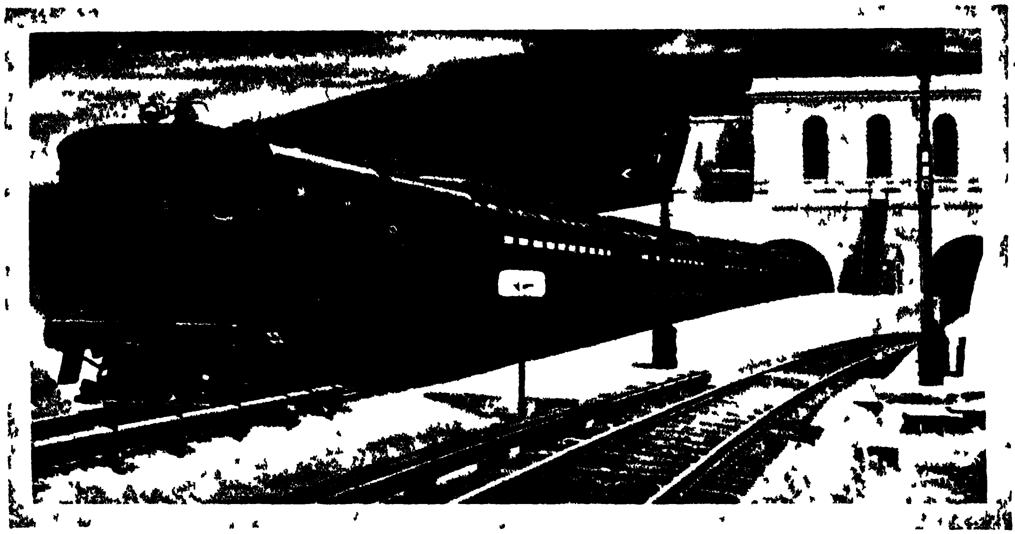


Photo by Pennsylvania Railway

Probably it does not occur to many people to be surprised that they can get on a train in New York City and soon find themselves bowling along toward Philadelphia without having caught even a sight of the mighty Hudson. Yet though there are ferries across the river, the travelers have not taken them, and though there is a bridge, they have not crossed it Instead they have dived down into the earth, train and all, and crossed *under* the river Here is a whole trainload of them coming out into daylight again.

of about the same length There are over six hundred others, and often on a train in Switzerland you will be whisked and out of the side of a mountain until you are fairly dizzy Sometimes when the train has to climb, you will go spiraling up a steep grade inside the mountain, and you may come out right above the same church steeple you were watching when you went into the mountain, only now the steeple is a few hundred feet lower down than it was before.

Into this black hole, which is a tunnel in the German Alps, the hurrying trains will burrow like worms, to come out into the sunshine after some miles of total darkness.

In the United States the longest railway tunnel was finished in 1929, under the Cascade Mountains in the state of Washington. The railway there already had a tunnel two miles and a half long. But it still had to spend so much money clearing snow away from its tracks that it decided to go under the ground for nearly eight miles That cost about $16,000,000, but it took only about eighteen months to do the work There are many other great railway tunnels in America like the Moffat tunnel near Denver, six miles long, the Connaught tunnel in the Canadian Rockies, about five miles long, and the old Hoosac tunnel in Massachusetts built about half a century ago, and also nearly five miles in length a wonder for its day And of course there are thousands of shorter tunnels.

Nor do the railways dig all the tunnels It is still more natural to carry water underground There is a great water tunnel in France, from the city of Marseilles to the river Rhône, over four miles away It is six times as large inside as the average railway tunnel And in the Far West is the Colorado River Aqueduct, the most remarkable tunneling operation in history. It has 108 miles of tunnels and brings water

242 miles from the Colorado to cities in southern California. The West Catskill Aqueduct, bringing water from the Delaware River to New York City, has a tunnel 85 miles long—the longest in the world.

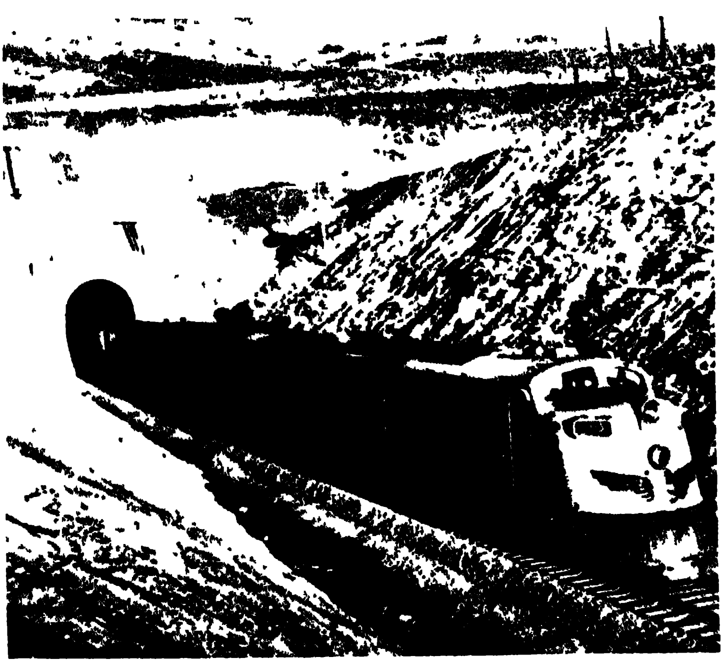
New York has needed many tunnels under the rivers that surround the island. The subways go under the East River to Brooklyn, under the Harlem to the Bronx, and under the Hudson to New Jersey. The Pennsylvania Railroad comes under the Hudson from the south, and the trains may go on east under Long Island Sound. And through the Holland and Lincoln tubes thousands of motors cross beneath the Hudson daily. There are similar tunnels in other cities and in other lands—like the Posey tunnel for motor cars in California, in which the air is changed about forty times every hour, and the great tunnel under the Severn River near Bristol in England

As there are many kinds of tunnels, there are many ways of making them One is with drills and dynamite, as we have said. But what good are drills and dynamite in the mud beneath a river? How can we make a tunnel through mud and water that will fill it up again as fast as we can dig it?

There are two main ways. One is to fill the tunnel as we go with compressed air. The pressure of such air will keep the mud and water from running into the hole we are making, and will let us dig ahead. The other is to run a great shield of steel into the ground—a big steel box as large as the tunnel we are digging It holds up the mud and keeps out the water, and as fast as we can go it is pushed on through them. Then the firm tunnel of steel and concrete follows in its path.

Yet there is still another way of making a roadbed under water, as used in the Posey tunnel The whole tunnel is built, in sections, on the land Then a great trench is dug in the dirt at the bottom of the river, and the frames of steel, filled with concrete, are sunk into the trench and joined together to form the roadway through. A good many tunnels have been built in this way.

But however we do it, whether through the rock or through the mud, we need a great deal of skill and a great deal of money to carve out a tunnel through old Mother Earth Every tunnel has its own peculiar puzzles for the engineer, and it does not always tell him when and where they are coming That is why the building of a great tunnel is an engineering feat



The streamlined "City of Los Angeles" is just emerging from the Altamont Tunnel in Wyoming It was the first train to pass through this 6,706-foot bore, which was completed late in 1949. After a visit to the spot it is not hard to understand the reason for building the road through the mountain rather than over it.

Photo by Union Pacific Railroad

TRANSPORTATION

Reading Unit No. 9

HOW WE SPAN THE FLOODS AND CHASMS

Note: For basic information not found on this page, consult the general Index, Vol. 15.

For statistical and current facts, consult the Richards Year Book Index.

Interesting Facts Explained

Why bridge owners charged a heavy toll in olden times, 10–209

How commanders sent their armies over makeshift bridges, 10 210

What a cofferdam is, 10–212

Where the Romans built stone arched bridges, 10–212

The order of Bridge-building Friars, 10–213

Cantilever bridges, 10–214

Marvelous suspension bridges, 10-214

Things to Think About

Why were great cities built near the bridges?

How are the stone foundations for bridges placed in position in river beds?

What sure way do we have of judging how civilized a people has become?

What different types of bridges do we have in the world to-day?

Picture Hunt

What kinds of bridges do we find in backward lands and in out-of-the-way parts of our own land? 10 209

Why were bridges covered in early colonial days? 10-212

Related Material

What kind of bridges stretch across the rivers in the Congo jungle? 5–467

How does Nature make bridges? 1–53, 96

How is compressed air used in the building of bridges? 1–462

How do we make iron into steel? 9-401, 403-8

What happens to the wire in the George Washington Bridge in winter and in summer? 1–478

When did the Iron Age begin? 9–399, 12-2, 6, 8

Summary Statement

The old Romans built arched stone bridges over rivers and deep, dry valleys; many a modern highway crosses deep valleys and rivers over such viaducts, and many a train passes over them in order to cross mighty mountain ranges. But to-day we build our viaducts of steel rather than of stone.

Photo by Deutsches Museum

Before steel bridges came bridges of wood and stone, and before them came primitive bridges such as this hanging bridge in the East Indies. Even now, not only in more backward lands but in out-of-the-way parts of such lands as our own, these swaying bridges of grass rope or cable span many a chasm or stream.

HOW WE SPAN *the* FLOODS *and* CHASMS

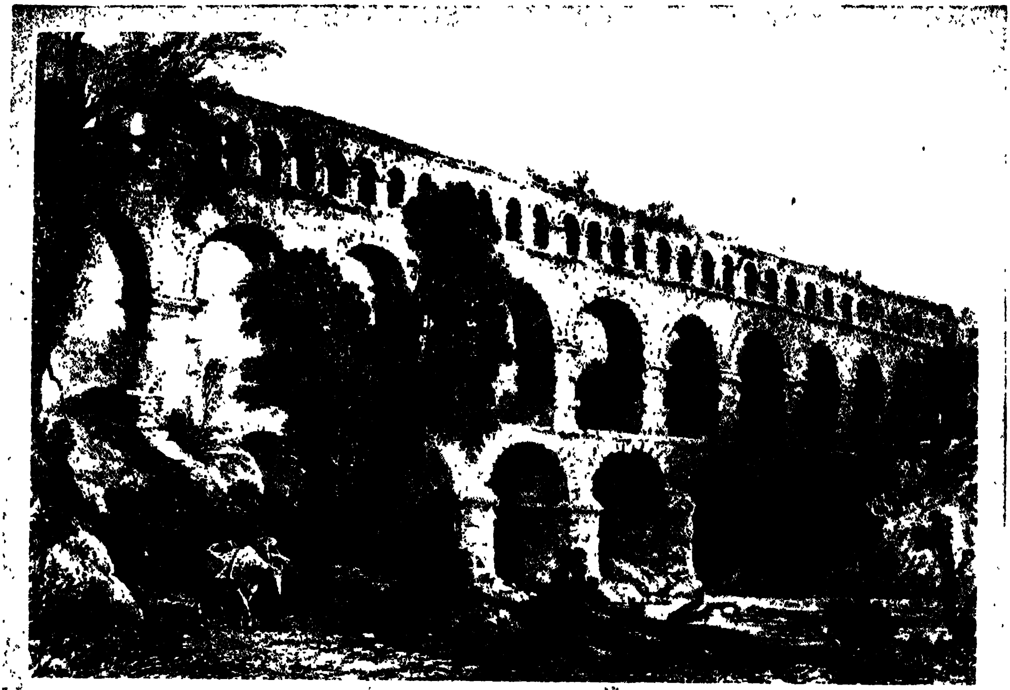
Beginning with Some Tree or Grapevine Thrown across a Little Stream, Man Has Learned How to Leap the Mighty Rivers with Graceful Arches of Suspended Steel

WE HAVE grown used to bridges—so used to them that we hardly notice when our train thunders over one. It seems the most natural thing in the world. But it was not always so. Many were the hurried travelers who in icy weather stood on the river's brim and shuddered before they could get up courage to plunge into the swift current; and many were the horses and riders who were lost when a weary creature tried to make the opposite shore with his rider on top of him.

Of course rivers crossing the main roads had little rowboats in which a ferryman—almost inevitably on the opposite shore—would ferry one across for a fee. But one had to wait if the ferryman was away from home or busy eating his dinner, and many a traveler, pressed for time, must have longed for a pair of seven-league boots to speed himself over a stream.

It is not strange, therefore, that in the olden days the city or nobleman owning a bridge charged a good round toll to anyone crossing it, and barred the approach with a gate. And it is not strange, either, that some bitter battles have been fought for the possession of various bridges. We all know the story of the brave Horatius. There have been many other warriors who played much the same rôle. For history tells us that kings and queens have been captured, cities lost and won, and even the fate of nations decided by what took place on a famous day at this or that famous bridgehead.

The first bridge must surely have been a tree that had fallen across a stream. Almost anyone who has camped out in the woods has ventured across a bridge like that. The second kind of bridge probably came when someone cut down a tree and threw it over a brook. And then came some sort of hang-



One of the finest of the old Roman aqueducts still standing is the Pont du Gard (pōN dü gȧr) at Nîmes (nēm), in Southern France. It has, as we see, three tiers of arches, arranged in beautiful proportion. The waterway was on top of the highest tier. This bridge is thought to have been built about 18 A.D.

ing bridge, such as savages and mountaineers still make. They stretch long ropes of hemp or grass or vines across a stream, and then fasten either a rope ladder beneath them or wooden slats across them, to make the passageway. And a swinging, perilous crossing it is, you may be sure!

But you could not drive a motor car across a bridge like that, or even ride a horse over it. Civilized people must have strong, lasting bridges, which will stand constant traffic and heavy loads. As a matter of fact, there is no surer way of judging how civilized a people has become than by looking at its bridges.

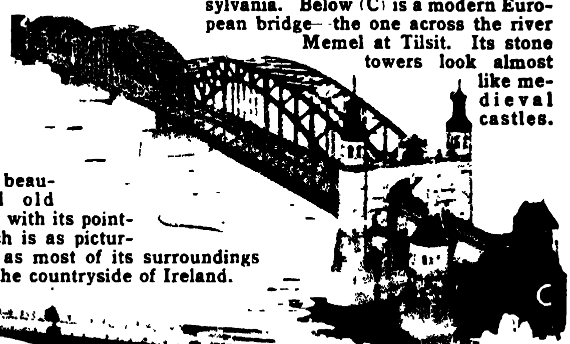
Makeshift Bridges

Of course, as the business of mankind goes on, we often have to put up temporary bridges, such as the pontoon bridges that rest on boats anchored in the stream. Those were made very early in history, and have helped to move the armies of many a great commander, for they are quickly built. Then there is the trestle, that open crisscross of timbers that is often thrown across a valley when work is under construction. But it is the permanent bridges that we are interested in here.

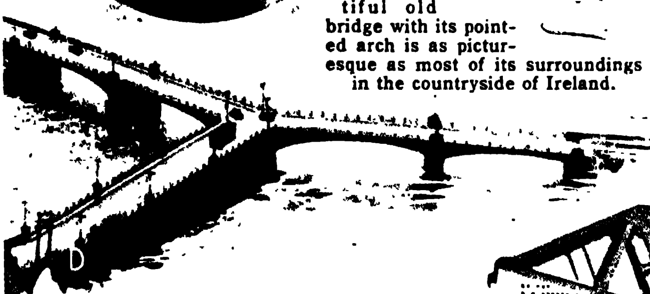
Building a Modern Bridge

It is not so very hard to build a strong bridge over a little stream. Piles, like stout pillars, have to be driven into the ground on each side, or else a stone or dirt abutment has to be built for a support; then timbers are laid across the stream between the abutments. The distance from one pier or abutment to another is called a span, and a span of ten or twelve feet is easy to construct. But when the builder comes to a wide stream with a channel of flowing water in the center, he has a much harder task. He must place some sort of foundation out in the river to rest his bridge upon, either because the timbers will not reach across the stream or because they will break under the weight of traffic if they are not supported in the middle. The oldest bridges all had a short span and very wide piers, but as the builders grew

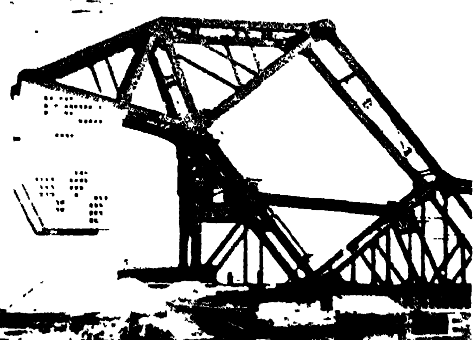
Above (A) is a fine American railroad bridge in Pennsylvania. Below (C) is a modern European bridge—the one across the river Memel at Tilsit. Its stone towers look almost like medieval castles.



This beautiful old bridge with its pointed arch is as picturesque as most of its surroundings in the countryside of Ireland.



D. This bridge at Zanesville, Ohio, is built in the form of a letter Y so that it can lead to three places at once.



E. Here is one end of a big jackknife bridge, the St. Charles Air Line Bridge at Chicago. The huge hopper at the left of the picture is full of weights. When the bridge is released at the other end the weights lift it into the air; then a ship can pass beneath. F. This is the cantilever bridge over the Firth of Forth in Scotland, one of the longest in the world.

surer of themselves they gradually lengthened the span to as much as seventy-five feet and narrowed the piers, in order to save their masonry as much as possible from the wear and tear of the current. To-day our suspension bridges reach across great rivers without touching the water except for a few feet at either bank.

In order to make his foundations deep and firm, the builder of a bridge of wood or stone must often get the water out of his way. To do this, he constructs a "cofferdam" around the spot where the pier or support is to go. A cofferdam is a wall of logs or planks or other material built to inclose a space. When the water is pumped away from inside it, a clear space is left to the river bottom, and men can go down to dig up the mud and place the stone foundations. Once the foundations are laid and built up above the water line, the dam is taken away and the river flows back in around the pier.

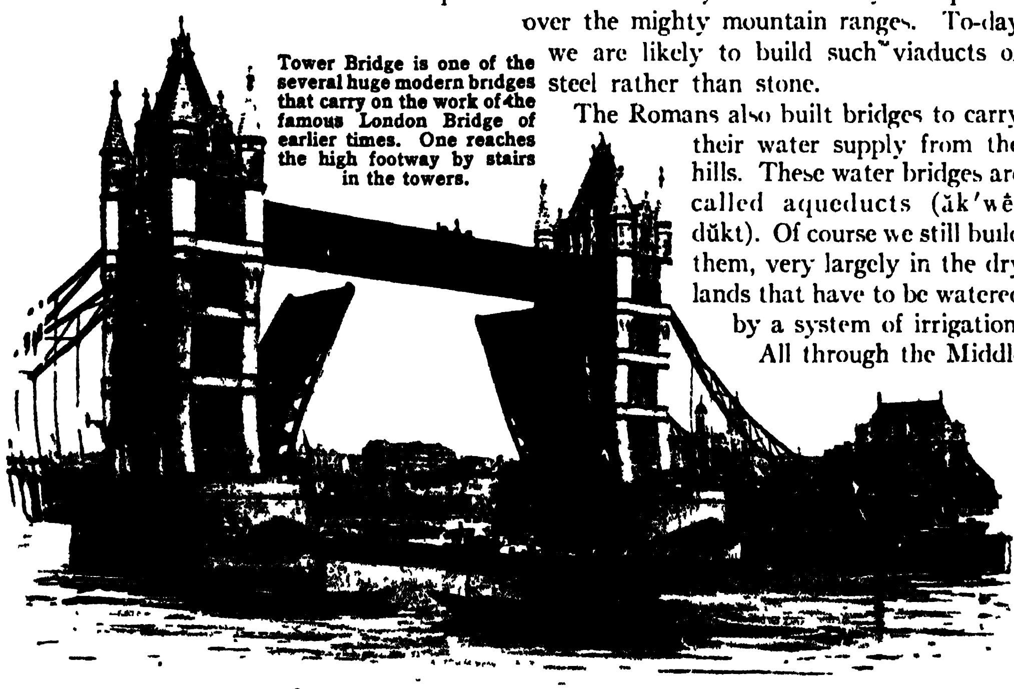
Photo by Virginia State C of C

This "humpback bridge" near Covington, Virginia, is one of the few old covered wooden bridges still standing. A covered bridge was a great protection in the days of Indian wars.

But then comes the problem of making the span from pier to pier. Centuries ago the Romans solved this difficulty by building arches of stone. Up to a hundred years ago, all the great bridges of the world were made with such arches running from pier to pier. Thousands of bridges are still built in that way, although now we often make them with reinforced concrete instead of with wood or stone. Reinforced concrete is merely concrete strengthened with steel. Arch bridges are among the most graceful things that men can build. Is there any more charming sight than the fine curves of a well-built bridge seen across the flowing water, through a vista in the trees?

Those old Romans built arched bridges not only over water but over deep, dry valleys. Such bridges are called viaducts (vī'ȧ-dŭkt). Many a modern highway crosses deep valleys over great viaducts, and without viaducts our railways could scarcely have passed over the mighty mountain ranges. To-day we are likely to build such viaducts of steel rather than stone.

The Romans also built bridges to carry their water supply from the hills. These water bridges are called aqueducts (ăk'wē-dŭkt). Of course we still build them, very largely in the dry lands that have to be watered by a system of irrigation. All through the Middle



Tower Bridge is one of the several huge modern bridges that carry on the work of the famous London Bridge of earlier times. One reaches the high footway by stairs in the towers.

Photo by G. W. R. Railway

Photo by Authority of the Port of N. Y.

One of the greatest triumphs of modern engineering is the George Washington Bridge over the Hudson at New York City In length of span it is second only to the Golden Gate Bridge in San Francisco Besides the walks for pedestrians, there are eight lanes for vehicles and space for four pairs of tracks Because of the enormous cost of building this bridge, everyone has to pay toll for the privilege of crossing it—but it is worth it, if only for the beauty of the steel structure and the magnificent view up and down the river. Our picture shows the bridge just before it was completed and opened in 1932.

Ages the people of Europe passed in procession back and forth across their bridges They had to build them thick and strong, for there were no great central governments to see that they were kept in repair. Often a stout bridge would crumble away, pier by pier, with no one to rescue it, for the labor of building a stone bridge is very small in comparison with the labor of keeping it up while century after century nibbles away at it with heat and frost and rain and wind. At one time there was an order of Bridge-building Friars, who made it their great work to build bridges and keep them in good condition Historians say that one can tell the age of a ruined bridge by looking to see how stout and thick it is; for as time went on and Europe became more orderly, it was not necessary to build as though no repairs were ever likely to be made.

Great cities arose near the bridges. At the point where London Bridge sprawled across the Thames, traders had to stop, for they could not get past it to go farther up

the river. So both roads and ships came to the city, and the great bridge was the center of a bustling trade. Tower fortresses stood at each end of it, and its whole length was lined with busy shops, whose rental helped to pay for repairs. Across it and around it and under it swirled the life of the city. This famous old bridge long ago gave way to a more modern structure, but you may still see a few city bridges lined with shops, like the Rialto at Venice, for instance, perhaps as famous as London Bridge itself; for in the great days of Venice it was the "stock exchange" of the city and one of the greatest financial centers in the world.

Bridges Built of Steel

It was not until our own Age of Steel that men learned to build really modern bridges, or any sort of bridge that would not interfere more or less with commerce on the river below. In the year 1823 was built the first steel bridge. Since then bridge building has grown into one of the marvels of the modern world. Highways leap across yawning chasms, bridges tilt or twist or whirl to let the boats go through, and some of our mightiest rivers are spanned with delicate curves of steel.

When the bridges are fairly small and low, the engineers have many cunning ways to let the boats get past them. There are elevator bridges, which climb straight up into the air like any other elevator, supported by a strong steel tower at either end. There are revolving bridges, which turn on a pier at the center as on a pivot. There are "bascule" bridges that break open at the middle and let each half swing back and up out of the way, and others, called "jackknife bridges," which lift from one end, like a knife blade. There are still others that are built high above the water and carry their passengers and freight in a great car swung beneath them on strong cables—a sort of aërial ferry.

Arched bridges are now often made of steel. The largest one in the world, in Sydney, Australia, has a span of 1,650 feet. Even longer spans may be made with the cantilever (kăn'tĭ-le'vẽr) bridge, in which the steel reaches out on each side of a pier until it meets the steel from the next pier. The largest bridge of this type is in Quebec; its span is 1,800 feet. But most small steel bridges are truss bridges, in which the span is supported by long, straight pieces of steel riveted together in trusses, or sections of rigid framework.

Most marvelous of all are the suspension bridges. To build a suspension bridge the engineers string enormous steel cables from towers on each bank of the river, and then hang the bridge itself from those ropes of steel. Many of these great bridges are not only incredibly strong but as beautiful as any bridges in the world. Their clean, strong lines sweep in the loveliest of curves, and their cables and girders make geometric designs that are the delight of artists and all lovers of beauty. Americans used to boast of the skillful engineering and the simple beauty of Brooklyn Bridge, but now a much greater wonder has been built on the other side of the continent. This is the Golden Gate Bridge across the famous Golden Gate in the harbor at San Francisco. It cost $35,000,000 and has a span of 4,200 feet, much longer than that of any other bridge in the world. It is one of the beauties of the great harbor whose entrance it spans.

Silhouetted against the evening sky, Brooklyn Bridge is like the spreading web of a giant spider.

Reading Unit No. 10

WHEN STEAM TOOK OVER THE WIND'S WORK

Note: For basic information not found on this page, consult the general Index, Vol. 15.

For statistical and current facts, consult the Richards Year Book Index.

Interesting Facts Explained

"Fulton's Folly," 10-217-18
How many steamboats had been launched before the "Clermont," 10 218
Where Fulton got the engine for his boat, 10 221
When steam conquered the Atlantic, 10-222
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Picture Hunt

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What has revolutionized the steamship? 10 222

Related Material

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What are the great advantages of the gyrocompass? 1 291, 10-457
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What work do steam turbines do? 1 506-8
Why were the Mississippi steamboats "so ugly that they were beautiful"? 7-214-15, 218, 247
How are steamships navigated? 10 299-300, 304
How is food kept fresh on long ocean voyages? 10 518
How do sailors know when to prepare for storms? 1-278

Leisure-time Activities

PROJECT NO. 1: Make a model of Fulton's "Clermont," 10-218

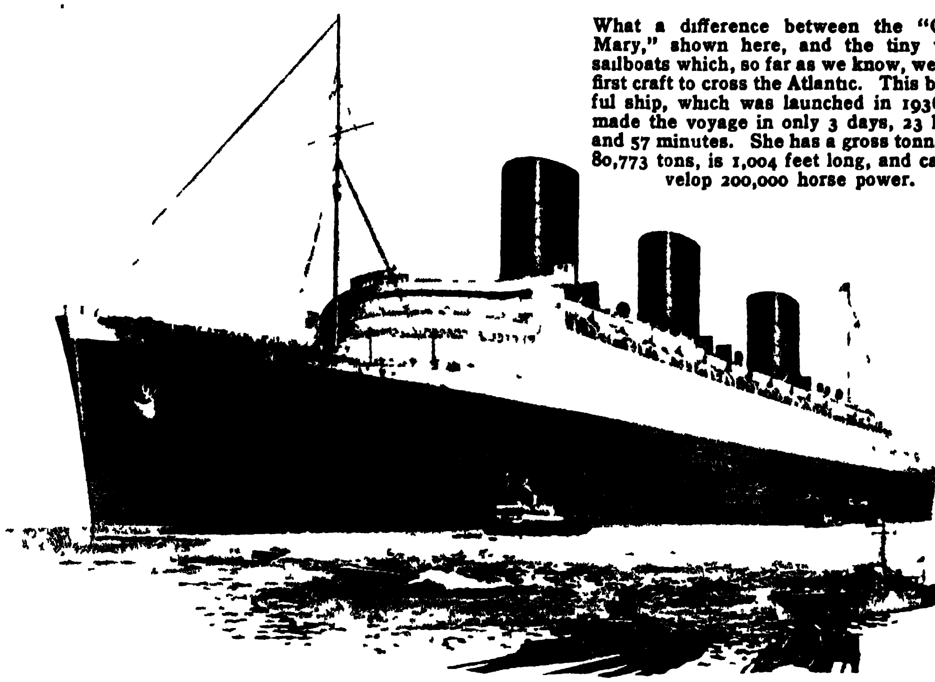
PROJECT NO. 2: Find pictures of the half-dozen largest liners in the world

Summary Statement

The coming of the modern steamship has meant that in less than a century the earth has shrunk in size until the farthest isle in the South Seas is nearer home for us than plenty of cities in our own land were two or three generations ago.

Photo by De Witt Ward

Before the days of the steamboat, the Battery in New York City must have looked a good deal like this. The artist, Ezra Winter, has shown us the graceful sailing vessels, built strong and tall and swift for the stormy trip around the Horn to China. It took the steamers a long time to drive these ships from the sea. Indeed the first true "clipper ship" was not built until 1832; and it was the clippers, not the steamers, that made American shipping famous in the middle of the nineteenth century. Many an old sailor remembers how he sailed before the mast; and even to-day these great white wings are sweeping across the ocean.



What a difference between the "Queen Mary," shown here, and the tiny viking sailboats which, so far as we know, were the first craft to cross the Atlantic. This beautiful ship, which was launched in 1936, has made the voyage in only 3 days, 23 hours, and 57 minutes. She has a gross tonnage of 80,773 tons, is 1,004 feet long, and can develop 200,000 horse power.

WHEN STEAM TOOK OVER *the* WIND'S WORK

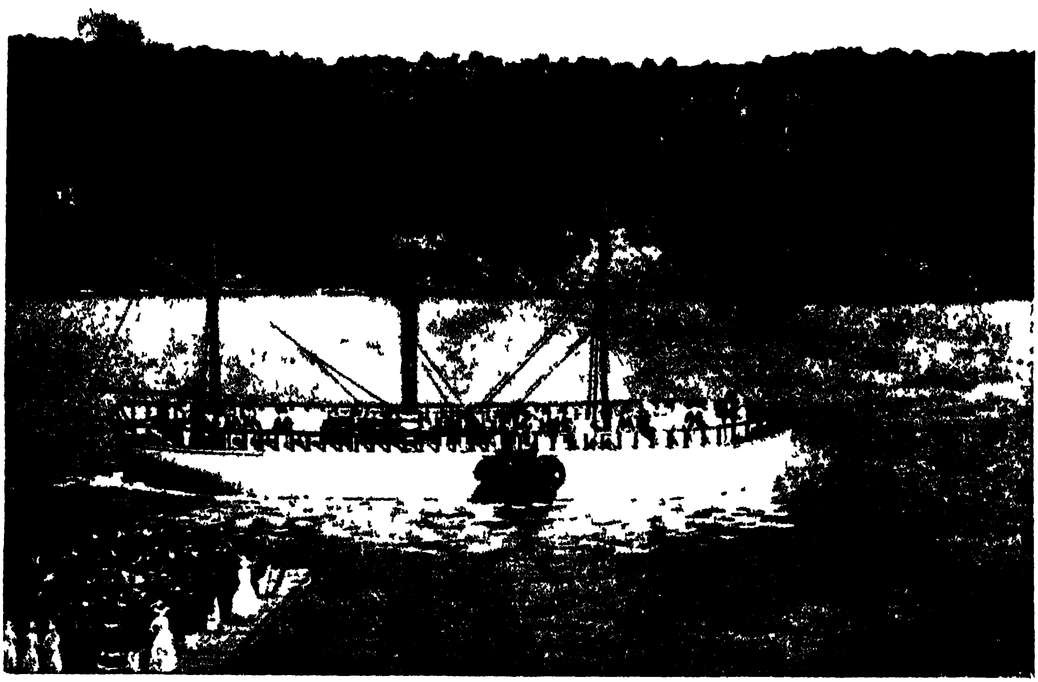
For Thousands of Years We Had Nothing but Muscle to Pull Our Carts and Nothing but Winds to Blow Our Sailboats. Only a Century Ago We Put Steam behind Both; and Look at What Happened!

ON A CERTAIN August morning in the year 1807, the waterfront around the old State Prison in the bustling little city of New York was thronged with a curious crowd. Those who could not get into the ranks lining the Hudson had climbed on top of boxes and wagons or were leaning from second-story windows, craning their necks for a view of the wharf. A few days before, the "American Citizen" had announced that "Mr. Fulton's ingenious steamboat" would sail that day for Albany. The newspaper went on to say that going with the current the steamboat was said to be able to make four miles an hour, or about the rate at which a fast walker can travel. Now all eyes were turned upon the strange craft with its big paddle wheels at the sides, its engine amidships, and its sails fore and aft—for it still had sails.

Moving about the boat was a tall, handsome man of forty-two, his dark eyes intent, the brown curls on his forehead damp with perspiration and excitement. It was Robert Fulton, who had come to the most important moment of his life But he was very quiet, and appeared not to notice the plainly audible remarks of the crowd concerning "Fulton's Folly."

He gave the signal to start. The boat did not move. The crowd broke into loud jeers. But Fulton kept steadily working until the trouble was remedied. At last, at one o'clock, the boiler began to hiss, the hawser

was drawn in, the side wheels began to quiver, and then slowly to revolve. A hush fell upon the throng In silent amazement the onlookers watched "Fulton's Folly" move out into the stream. The engine belched great clouds of black smoke, steam hissed from the joints, and the crude machinery groaned aloud. But the boat started up the river.



When Robert Fulton's first little steamboat, the "Clermont," started up the Hudson from New York that August day in 1807, bound for Albany, people laughed and called her "Fulton's Folly." But here she is steaming past the Palisades in perfect trim, about to make good her boast and confound the scoffers. Fulton had a monopoly of steam transportation on the waters around New York, so other experimenters had to go to other rivers or build up lines along the coast. Thus the use of steamers spread.

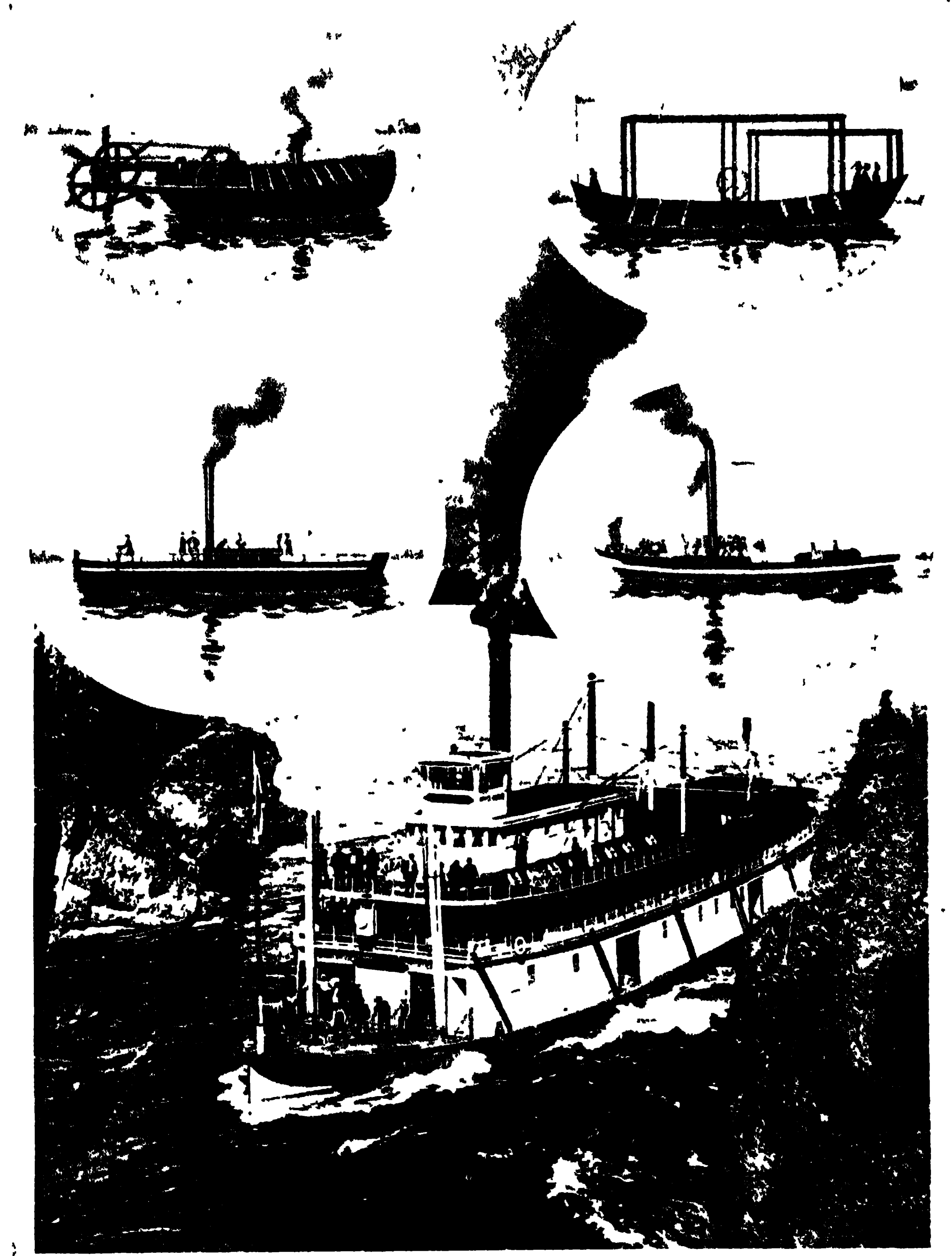
The Triumph of the "Clermont"

So began the first voyage of the famous "Clermont" She made the trip to Albany, a hundred and fifty miles away, in thirty-two hours of sailing time. On the return voyage she reached New York in thirty hours. Both ways she had gone in the face of a head wind, so that her sails had not been used. On the first night she tied up at Clermont, the beautiful estate of Robert Livingston, a wealthy and influential gentleman who was backing Fulton on his venture. There were great doings at Clermont that evening, for a party of friends of Fulton and Livingston were making the trip on the steamboat. Among the guests was handsome Harriet Livingston, a niece of Robert Livingston. Her engagement to Fulton had been announced soon after the steamer had made its triumphant departure from New York

Much has been made of this first voyage of the "Clermont" and of its good record afterwards when it went into regular service between Albany and New York. It is true that it was the first steamboat to make a profit for its owners, but it was not by any means the first to be invented and launched. Indeed it was the sixteenth steamboat to run in American waters, and others had been built and launched both in France and England.

The Very First Steamboats

The Romans had understood the principle of propelling boats by means of paddle



They look very funny to us to-day, those first efforts to build a steamboat. In the upper left-hand corner is the one built in 1706 by Jonathan Hull, an Englishman. To the right of it is what many people regard as the world's first workable steamboat—the little affair that John Fitch rigged up in 1788. It was propelled by steam-driven paddles. At the left center is the tow-boat built by Symington for Lord Dundas in 1803; and at the right center is the "Comet," built by Henry Bell in 1812. Below them is a modern river boat.

wheels and had employed slaves to do the turning. Almost as soon as it was discovered that steam would make factory wheels go round, men began working to find some way of making it propel paddle wheels on boats. In 1736 Jonathan Hull of England took out a patent for a paddle boat worked by steam. It was to be employed for towing canal barges, and "not to be used in storm or when the waves are very rough." Fifty years later, James Rumsey launched on the Potomac River a boat which was operated by steam and made four miles an hour. He died before his invention was patented; and, anyway, our country was then too busy trying to build itself into a nation to pay very much attention to builders of steamboats.

Photo by American Museum of Natural History

Flatboats like this one carried nearly all the trade down the Mississippi until the steamers came, and even then they did not disappear for two generations. Lincoln in his youth operated one of these stubborn little boats.

Working with Rumsey was John Fitch, who soon left him to try some ideas of his own. After years of trial and error, Fitch succeeded in getting a steamboat on the Delaware River to make seven miles an hour. But by the time his patent was granted his money had all run out. He went to England and to France, trying to get wealthy men interested in his invention, but to no avail. "The day will come," he cried in his despair, "when some powerful man will get fame and riches from my invention; but no one will believe that poor John Fitch can do anything worthy of attention." Fitch died in poverty and discouragement only a short time before Fulton's triumph.

A Born Inventor

From his earliest boyhood on the Conestoga River in Lancaster County, Pennsylvania, Robert Fulton had shown an inventive turn of mind and a natural liking for machinery of all sorts. His parents were so poor that he could get little or no schooling, so he was apprenticed to a watchmaker. He learned the trade, but he was more interested in the collection of ship models made by a Mr. William Henry of Chester County, who had spent many a year trying to make a workable steamboat.

Fulton Turns to Art

At the age of twenty-two, Fulton, who was also gifted as a painter, went to England to study under Benjamin West, the great artist. He painted some very good portraits, but it was not long before the inventive side of him won over the artistic. He gave up painting and went to France to make experiments with torpedoes and steamboats. He tried unsuccessfully to interest the French government in his torpedoes, which would have proved most helpful in the war France was then waging with England.

Everywhere at this time there was a great interest in the idea of the steamboat. In Scotland, Fulton saw Symington's "Charlotte Dundas" steaming along the Firth and Clyde Canal with barges in tow. He corresponded, too, with Henry Bell of Glasgow, who tried without success to get the British government to back his ventures in steam navigation. Lord Nelson, the famous admiral, was himself in favor of Bell's ideas, and said to the stubborn heads of the British Admiralty, "My lords and gentlemen, if you do not adopt Mr. Bell's scheme, some other nations will, and in the end vex every vein of this empire." By 1802 Bell had a little steamer, the "Comet," in regular service between Glasgow, Greenock, and Helensburgh, where his wife had bought a flourishing seaside hotel. That was the beginning of the great shipbuilding industry on the Clyde.

In France Fulton saw some of John Fitch's plans, which the unfortunate inventor had left with an American consul. Best of all, in France he met Robert R. Livingston,

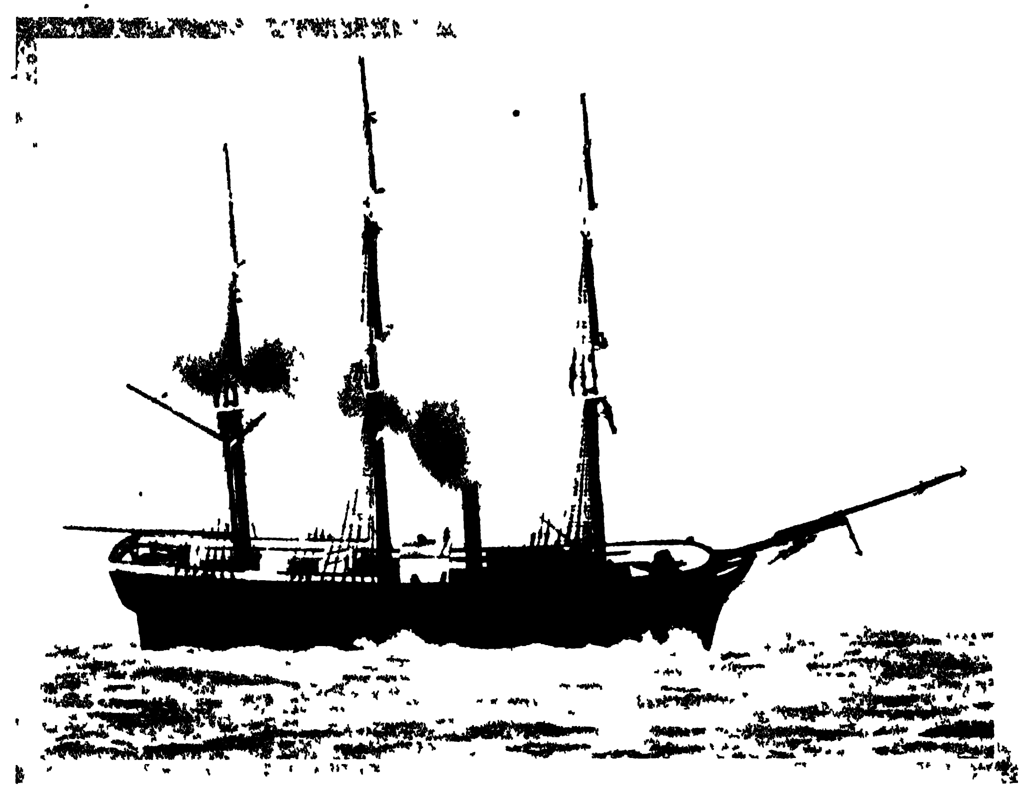


Photo by Museum of Science & Industry N Y C

This is the S S. "Savannah," the first ship to use steam in crossing the Atlantic. To tell the truth, she looks a good deal more like a sailing vessel than like a modern steamer, and we need not be surprised that she used her sails for all but eighty hours of the trip. After taking on much-needed coal at Liverpool, she went on into the Baltic, where she made a great stir with her odd adventure. Of course she was only a curiosity!

who, as United States minister, was intrusted with handling the purchase of the great Louisiana Territory. Now it happened that Livingston, wealthy, prominent, and an influential statesman, was immensely interested in steam navigation He and Fulton put their heads together, and before long Fulton was back in England to order from the famous engine works of Boulton and Watt an engine for the boat he planned to launch in America This was the "Clermont," the first of the successful steamboats run by Fulton and Livingston on the Hudson and on other rivers in New York, as well as on the Ohio. They started, too, steam ferries from New York to Jersey City and to Brooklyn. The ferries could carry four hundred passengers and thirty carriages at a time.

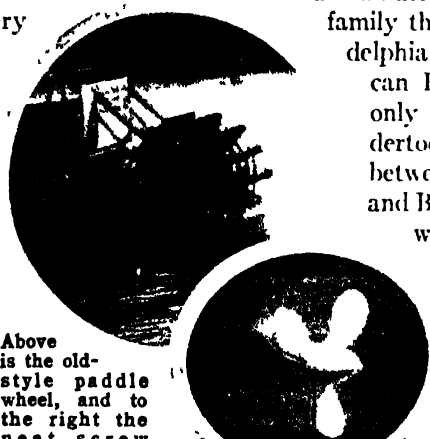
In 1812 when England and the United States were at war—fighting all their naval engagements with sailing ships, of course—Fulton planned a big steam battleship for his government's use But before she could be finished he died, and she never went into service.

"A Fearsome Wild Fowl"

Just as the success of airplanes soon brought up the question as to whether they could fly across the ocean, so the invention of steamboats for rivers soon set men wondering about crossing the Atlantic with steam instead of sails. There were plenty of people to declare the notion ridiculous "You might as well talk of going from New York to the moon by steamship as to talk of going from New York to Liverpool that way," they jeered. "Clearly such a thing would be flying in the face of Providence," said many of the devout. "Did not God send winds to hold back or to further sails? Would you go against his plans?" Besides,

steamboats were so dangerous! A Quaker by the name of John Q. Wilson wrote in his diary that when he told a friend he meant to go from New York to Albany in one of Fulton's boats, his friend exclaimed, "John, will thee risk thy life in such a concern? I tell thee she is the most fearsome wild fowl living, and thy father ought to restrain thee." And a skipper on a Clyde sailing boat said to his crew, on sighting Bell's "Comet," "Kneel down and thank God that ye sail with His ain win' and not with the devil's fire and brimstone, like that sputtery thing there!"

Such notions, however, cannot stop an idea whose time has come. The first little pennant of smoke that ever streamed out over the Atlantic came from the smokestack of the "Savannah." On May 24, 1819, Captain Moses Rogers took her out of Savannah, Georgia, bound for Liverpool. He intended to make the whole trip by steam if he possibly could. An entry in the ship's log shows why he could not. It says, "No cole to git up steam." The little ship simply could not carry along enough fat pine knots to stoke her engine for all those miles. The trip took twenty-nine days, and the sails were used even while the coal lasted. They were set for all but eighty hours of the trip.



Above is the old-style paddle wheel, and to the right the neat screw which replaced it. That simple little device is all that is necessary to send a great ship through the water. It has revolutionized the steamship.

When Steam Conquered the Atlantic

Not the "Savannah," but a little Dutch ship built in Dover and called the "Curaçao" deserves the credit for being the first steamship to navigate the Atlantic. Beginning in 1827, she made mail trips for a year or two between Holland and the Dutch West Indies, traveling under steam. To the "Royal William," built in Quebec in 1831, goes the credit of making the crossing under her own power from continental North America to England. She had been intended for service between Quebec and Halifax. But a trade depression and an epidemic of cholera spoiled her chances for success there, and so her owners decided to send her across to be sold in London. In 1833 she made the crossing from Quebec in seventeen days, burning 330 tons of coal to keep up her 180 horsepower. She sold for $50,000 and ended her days in the Spanish navy.

The Birth of a Great Ship Company

One of the owners of the "Royal William" was Samuel Cunard, born of a Quaker family that had moved from Philadelphia to Quebec after the American Revolution. When he was only twenty-seven, Cunard undertook a British mail service between Boston, Newfoundland, and Bermuda. His dearest dream was a transatlantic steamship service. Twenty years after the "Savannah's" staggering effort, Cunard went to England and got Robert Napier, the great shipping engineer of the Clyde, and David McIver and George Burns, two influential shipping men, interested in his scheme.

These four started the famous Cunard Line, which had a contract to carry the transatlantic mails for the British government. They built four ships on the Clyde, and the first, the "Britannia," sailed from Liverpool to Boston, July 4, 1840. She was a wooden, paddle wheel steamer of 1,154 tons, 207 feet long, with 400-horsepower engines that ate up 38 tons of coal a day. Her speed averaged about eight miles an hour. When she arrived in Boston fourteen days and four hours later, she received a royal welcome. Cunard was on board and worried all the way across about her consumption of coal. Well he might, for it was at the rate of more than four pounds an hour for each horsepower developed. To-day a great liner like those that regularly cross the Atlantic burns a little more than half a pound of oil an hour per horsepower to send

her 50,000 tons over the sea at thirty-two miles an hour.

After this the captains of the sailing packets of the Black Ball Line, leaving New York for Liverpool regularly twice a month, had to stop laughing at the "smutty pots" belching smoke and lumbering over the water. Even the famous clipper sailing ships faded from the seas in the 1850's, after Donald McKay's beautiful clipper, "Sovereign of the Seas," raced the Cunarder "Canada" from New York to Liverpool and lost by two days, though she averaged better than twelve miles an hour all the way from the Grand Banks to Cape Clear.

When Wood Gave Way to Iron

Like all their competitors, the early Cunarders were all wooden ships with paddle wheels. But while wood was lighter and in some ways superior to metal for shipbuilding, experience proved that iron ships would last longer. Gradually more and more ships were built of iron, which gave way to steel toward the latter part of the last century. As for paddle wheels, they were all right for quiet lake and river traffic, but they were poor at fighting a way through the rolling waves, which sometimes sent one wheel clear out of the water while the other was plunged too deep to give much service.

It was the Swedish engineer John Ericsson, inventor of the battling "Monitor," who perfected the screw propeller, now universally used in ocean steamships. If the propeller shaft broke, however, a ship was helpless as a log and might drift about for weeks, while all on board might die of starvation if another ship did not come to the rescue. Because of this, twin screws were introduced, and some ships now have as many as four propellers. Screw propellers made it possible to build bigger and swifter ships. The great companies, like the Cunard, the Hamburg-American, the North German Lloyd, and the White Star lines, began to compete with one another. The Cunard built the "Mauretania" and the "Lusitania," which was destroyed by a German submarine in 1915. Each of these liners was 790 feet long, and had an average speed of more than twenty-five miles an hour. The White Star Line built the "Olympic" and the "Titanic," which was wrecked by an iceberg on her first voyage, in 1912, and went down with fifteen hundred passengers and crew on board. These ships were each 800 feet long, but not so speedy as the Cunarders. The Hamburg-American's "Imperator" was bigger yet, for she was 910 feet long. For some years the "Mauretania" held the speed record, but

Gongs sounding and flags flying, here we are off for the other side of the world! Shall it be London, Paris, or Naples? Or are we headed across the broad Pacific to the Orient?

Photo by French Line

she had to surrender it in 1930, when the North German Lloyd liner "Bremen" made the Atlantic crossing in four days, seventeen hours. Then, in 1936, the "Queen Mary," an English ship, made the trip in less than four days.

To-day the liners vie with one another not only for greater size and speed, but also for greater comfort on the voyage. The great liner is a kind of floating palace, with music rooms, ball rooms, palm gardens, gymnasiums, swimming pools, tennis courts, elevators, and all the luxuries to make them fit for royalty itself.

The biggest ships, the speediest, and the most luxurious are in the North Atlantic trade because there is more traffic there. But there are excellent lines to South Africa, South America, and Australia. Splendid liners go regularly back and forth from San Francisco, Seattle, and Vancouver to the ports of the Philippines, Japan, China, New Zealand, and Australia. The distance of more than six thousand miles across the Pacific is so great that only the biggest liners can take along coal enough for the voyage, and so a great many steamers stop to take on fuel in Honolulu, at the "cross-roads of the Pacific." But more and more ships burn oil instead of coal.

A Pageant of the Oceans

What a parade of steamships goes round the world that knew them not at all so short a while ago! There are the haughty liners rushing at twenty-five and thirty miles an hour, full of passengers impatient to reach land. There are the slower passenger and cargo boats, content to cross the Atlantic in a third of the time taken by the "Savannah." There are the specially-built fruit ships loaded with bananas from Central America and the West Indies, refrigerator ships carrying the frozen meats of South Africa and the Argentine to foreign markets, ships steaming down the Great Lakes heaped with iron ore for the steel furnaces, oil tankers bringing precious fuel to consumers all over the earth, huge colliers carrying coal out to fueling stations. And there is the tramp steamer, the wanderer of the waters. She may be a 2,000-ton vessel setting out from a Welsh port with coal for Canada. At Sydney, Nova Scotia, she may take on steel rails for Prince Rupert and have to go through the Panama Canal and up the west coast of North America. At Prince Rupert she may find a cable from her owner ordering her to put in at San Francisco for a cargo to Shanghai, and at Hongkong she may load cement for Australia. Then, after taking a cargo of coal around the coast of Australia, she may steam off for the home port with her hold full of wool. On the way, she may have the good luck to find a ship in distress and tow her in. Then her captain and crew will divide among them their share of a good proportion of the value of the ship and cargo they have salvaged.

Wonders of a Modern Steamship

How the little "Clermont" would rub her eyes if she could see the improvements that have come about in such a brief span of history: first, iron and then steel replacing wood for ships; coal and then oil taking the place of the pine knots her fireman stoked so hard that August morning; screw propellers, driven faster and faster by steam engines called turbines, taking the place of the paddle wheels that splashed the water of the Hudson River on any of her passengers who ventured too near on that maiden voyage up to Albany! And what would the funny little old "Savannah" and the "Curaçao" and the "Royal William" think of all the funnels of the leviathans of the deep sending their smoke plumes over all the seas of the world! In less than a century the earth has shrunk in size until the farthest isle in the South Seas is nearer home for us than plenty of cities in our own land were two or three generations ago. No wonder the nations of the world are coming to be one great family, with a multitude of interests to hold them together.

TRANSPORTATION

Reading Unit
No. 11

THE EYES OF THE STORMY SEA

Note: For basic information not found on this page, consult the general Index, Vol. 15.

For statistical and current facts, consult the Richards Year Book Index.

Interesting Facts Explained

How beacon fires guided the seamen of ancient Egypt, 10–226
The famous lighthouse on Pharos, 10–226
How far out at sea can the light of the modern lighthouse be seen? 10–226-27
What modern lighthouses are like inside, 10–227-28
The lighthouse lamp, 10–228
How the seaman knows what light he is watching, 10–229
Lightships and buoys, 10–228-29
Why lighthouses have undersea and radio signals, 10–229

Things to Think About

What prevents the lighthouse beacon from being seen for more than about twenty-five miles?
Why was a lighthouse called a "pharos"?
How is the light of the lighthouse lamps intensified?
Why are lightships used?

Related Material

What do we know about the lighthouse that was one of the seven wonders of the world? 5–181, 186
How does the Department of Commerce make life easier for pilots? 7–380
Why are "birdladders" now fixed below the lanterns of many lighthouses? 4–3-4
How was England warned of the approach of the Spanish Armada? 10–28
How has radio saved thousands of lives at sea? 10–121
Of what use are buoys when broken ocean cables have to be mended? 10–105
How does the radio compass help ships to find their position? 10–121
How are shoals built up? 1–57

Leisure-time Activities

PROJECT NO. 1: Build a model lighthouse, 14–34

PROJECT NO. 2: Write a story about a lighthouse keeper.

Summary Statement

We do not often hear of a ship wrecked on rocks or coral reefs along some lonely coast because most of the dangerous shores of the world send messages across the watery darkness, and stare at the storm-tossed vessel with friendly, winking eyes.

Photo by L M & S Ry

Ever since men first began to "go down to the sea in ships" they have had to battle for their lives with the darkness and the storms The weapons of their battling are the skill of the seamen, the stoutness of the ships, such aids as compass and chart and steady rudder— and the help sent out to them from friendly shores If it were not for the signaling of the lighthouses, many and many a ship would go down in spite of all the improvements in shipbuilding, in spite of steam and compass and the seamen's best skill Above is the famous lighthouse at Holyhead, on the northwestern tip of Wales.

The EYES *of the* STORMY SEA

This Is the Story of the Great Lighthouses, Old and New, Which Have Saved Many a Gallant Ship from Dashing on the Rocks

A STORM at sea! Night, and the heavens black as pitch—the waves like moving mountains—the wind lashing the deck with rain And as the boat runs before the wind, how shall she know that she is not heading straight for some jagged rock that will tear her to bits, or for some treacherous sand bar where she will stick fast at the mercy of the waves? But if she can glimpse through the dark some familiar light, or catch the sound of some familiar warning signal, she will know where she is and which way she should try to go

So, for many centuries, men have put lights along dangerous coasts, to save ships and sailors from the dark and storm.

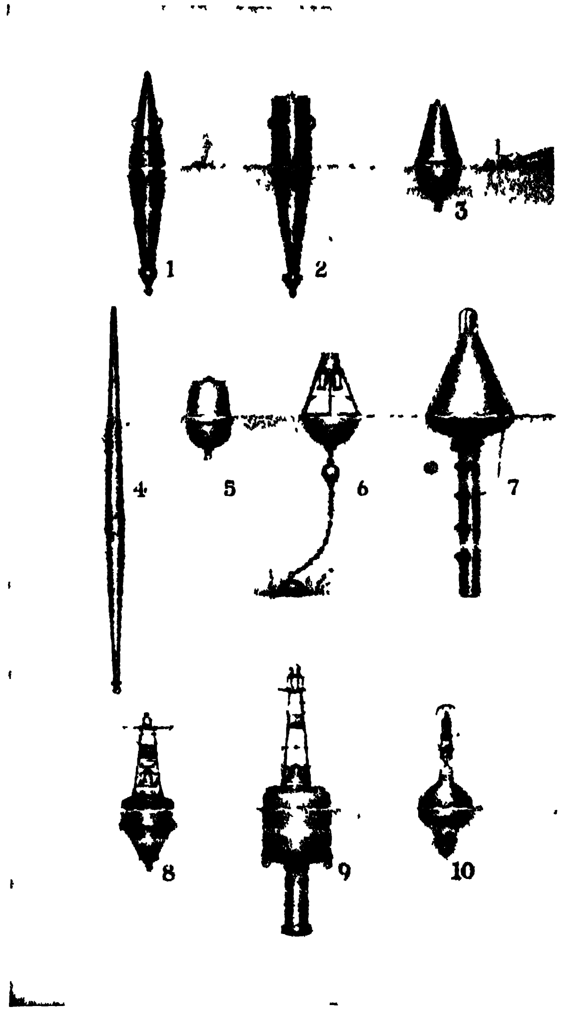
In ancient Egypt, priests often burned beacon fires for the seamen on the Mediterranean, and we have record of a lighthouse in Asia Minor in the seventh century B C Somewhere around 250 B C. a great tower was built on the island of Pharos (fa'rŏs), near Alexandria in Egypt, and light streamed from it far over the water This lighthouse on Pharos was so famous that people called it one of the seven wonders of the world, and for centuries any lighthouse was called a pharos after it

Ever since the building of Pharos, there have been many lighthouses, some of them perched on headlands overlooking the sea, some clinging to rocky islets, perhaps half buried in the waves Yet it was not until almost our own times—around 1800 A D — that men found ways of improving much on that ancient light Till then, the light was only a fire of wood or coal, which of course could not be seen very far Nowadays incandescent oil burners or electric lamps are used, which often may be seen as far as the

curvature of the earth will allow—some twenty miles as a definite beam, perhaps a hundred as a light in the sky. Big mirrors reflect the light. All sorts of other improvements have been worked out, too, as we shall see.

But suppose we visit a lighthouse—one of the romantic ones, perhaps in remote Alaska. It stands with its feet always in the ocean, on a rock from six to twenty feet below the surface of the water. It will be a round tower of stone or concrete, strong beyond belief to stand against the rough handling of the waves. Every trick known to modern builders is used to anchor it securely on its storm-besieged perch. Interlocking steel sheet piling and reinforced concrete lend their strength to its foundation, which is solid as the rock it rests on.

If we had chosen a lighthouse not set on a rock, but anchored in shifting shoals or sands, we might have been told some very remarkable things about the building of it. Piles or anchoring beams had to be driven very deep into such a soft foundation. Probably the engineers used caissons (kā'sŏn), which are really huge metal boxes that can keep out the water around the foundations of the tower. Such a caisson can be anchored at the spot where the tower will stand and the foundation will be built in it. It sinks deeper and deeper into the sand with the weight. In the end it may be filled solidly with concrete or masonry, on which the tower itself can be built. The larger light stations have all the modern conveniences.



Buoys are the guideposts of the sea. They mark out channels, warn of shoals or sunken wreckage, show where a boat may anchor. They are colored and numbered according to an established code, so that the seaman knows the meaning of each one. Further, the unlighted ones are made in special shapes for special purposes: there are tall nuns (1), tall cans (2), nun buoys (3), iron spar buoys (4), can buoys (5). Some give sound signals: bell buoys (6), whistling buoys (7). Some carry lights: (8, 9, 10). They burn compressed acetylene gas or electricity, and often carry bells (8, 9), gongs, whistles, or trumpets just as other buoys do. You will always find buoys in harbors and at the entrances to important rivers. They are fastened by a chain to a heavy iron weight that lies on the bottom.

But we shall pick out a calm day to get on the boat and steam over to our lighthouse. Then the lighthouse keeper who is probably a member of our Coast Guard and trained to his task will lower his skiff and row alongside to take us off. As the skiff comes to the wall of the lighthouse, we must catch a ladder, and climb up perhaps twenty feet to a door in the side of the tower.

Yet once we are safe on the stone threshold, how solid everything is! The great wall is thirteen feet thick, and we pass through it in a small tunnel to the snuggest little room imaginable, right in the center of the tower. No matter how a storm may rage outside with furious, beating waves, this heart of the tower will be always quiet and serene.

The little room is just a vestibule to the interior. There are lockers around the walls, but no chairs or comforts of any kind. So we shall climb up those steep stairs to the floor above. Here we find a larger room filled with stores of every kind that a dweller in the sea may need. Everything is shipshape and orderly, but there is very little space in which to get around. Then up we go again, to an oil room full of tanks of gasoline and kerosene; then up once more, to another oil room Finally, on the fifth floor, we come to the lighthouse keeper's home.

It is a little round chamber with windows on each side, where you can look out over the windy waters. There are chairs and a table or two, and lockers, and a kitchenette in one corner. There will be pictures on the wall, too, and books and magazines on the table, and probably a radio. And everything will be neat and spotless as a captain's cabin at sea. Suppose you could come into this warm bright room on a cold winter night when the waves were breaking around the tower far below and the wind was whistling and howling at the windows. Would you not feel it was the safest and the snuggest spot in the world? If we go on up the stairs again, to the sixth floor, we shall find perhaps three little bedrooms for the lighthouse keeper and his helpers or his family, each just big enough for a bunk and a chest of drawers. How should you like to sleep in one of these tiny rooms in this high tower of stone? Should you like to lie on your pillow at night and listen to the waves lashing far below, or wake in the bright morning and look out of the little window far over the sea?

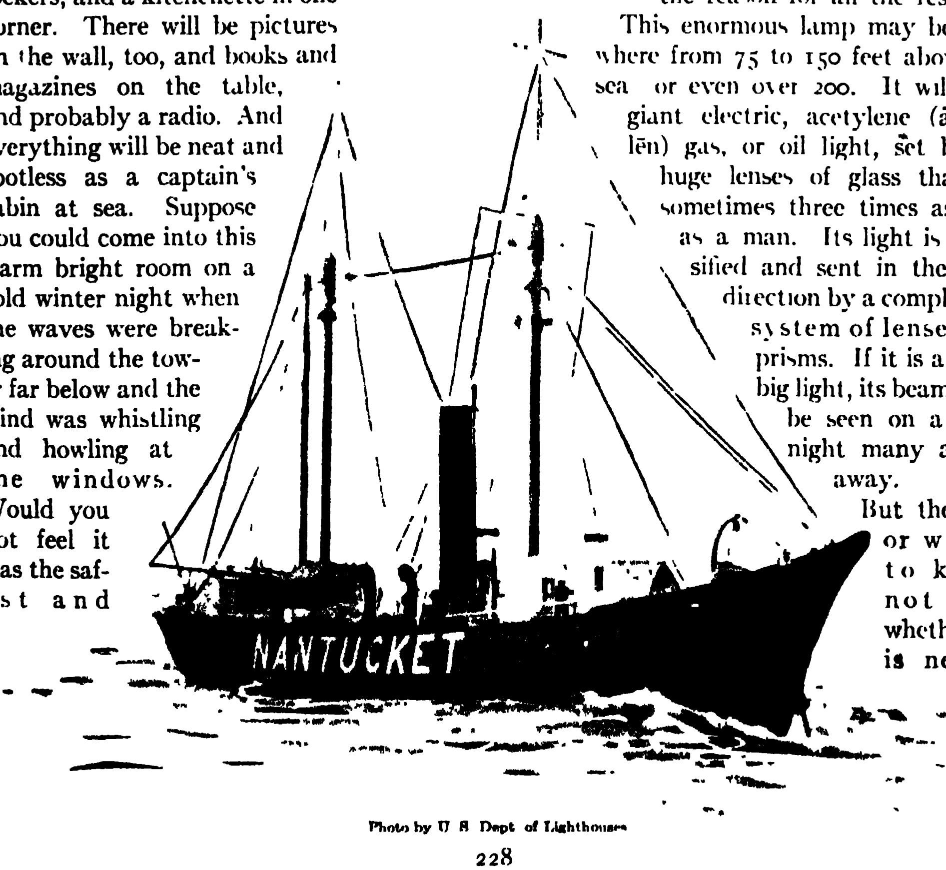
Photo by U S Dept of Lighthouses

This is the giant lens in the lighthouse at Kilauea Point, Hawaii.

But we must be climbing up once more, for above the bedrooms the real business of the lighthouse begins. There is a room full of machinery, and then comes the lantern itself, the reason for all the rest.

This enormous lamp may be anywhere from 75 to 150 feet above the sea or even over 200. It will be a giant electric, acetylene (ă-sĕt'ĭ-lēn) gas, or oil light, set behind huge lenses of glass that are sometimes three times as high as a man. Its light is intensified and sent in the right direction by a complicated system of lenses and prisms. If it is a really big light, its beams may be seen on a quiet night many a mile away.

But the sailor wants to know not only whether he is near a



The "Nantucket" is a lightship anchored off shore near the island for which she is named. Buffeted by every storm, she carries the light that is the first outpost of the New World for all ships entering New York harbor.

Photo by U S Dept of Lighthouses

coast, but just what coast it is. So of late years lighthouses have been made as different as possible from one another, in order to tell the sailors just where they are. Sometimes, especially in harbor entrances, different colors are used. A red light is not half so strong as a white light, and a green light is only about a quarter as strong; it is wasteful to use colors if there is any other thing to do.

Usually what the lighthouse builders do is to make their light flash on and off in some especial combination of flashes, rather like a Morse code. Perhaps there will be three sharp, short flashes of light, then a few seconds of darkness; and the seaman will know at once from the number and the order of the flashes just what light he is watching, and just where he is. Fairly few of our lighthouses simply send out one steady beam of light. In most of them, to be sure, the light really burns all the time. But it is shut off from view by a screen that works up and down or, more often, turns round and round like a sort of giant lampshade, making the light flash, grow dim, go out—flash, grow dim, go out.

Many of the tallest of the lighthouses are not in stone towers like the one we visited, but in buildings on the land, or in sea towers made of openwork iron and steel, like the skeleton of a skyscraper. Many lights, though of course not the highest, are on lightships instead of in buildings, or on buoys anchored in the water. More and more, clever men are working out ways to make the lights take care of themselves, and many a ship is saved by a light that keeps on burning for days without any keeper's coming near it.

But even the strongest light will be useless when there is a heavy fog. So lighthouses try to call to the ships, too. The oldest way is to ring bells, but bells cannot be heard very far through a thick fog. Guns and sound rockets, whistles and horns, are used. Certain sirens and sound-making machines called diaphones (dī'à-fōn) are the loudest.

Radio and electronics have brought wonderful aids to mariners. Radio makes possible speedy communication between ships and shore. Radio beacons on shore constantly send out signals by which ships equipped with direction finders take bearings in bad weather. Each beacon has its own signal—a special combination of dots and dashes known to navigators. As an aid to long-range navigation we now have the device loran (lō'răn). Ships carrying it can find their positions at any time. Most ships are also fitted with radar. It sends out signals from the ship which are "echoed" back to the ship by icebergs or any other objects in its path. They make tiny spots on the radar's screen.

So weather is being slowly conquered.

This loran receiver is aboard ship. The impulses which it receives and records are sent out by loran stations on shore. They operate in pairs and send out signals with exact timing in relation to each other. The difference between the time of arrival of the two signals at the ship bears a direct relationship to the difference in the distances between the ship and each of the two stations. The navigator uses this difference in determining his ship's position. Loran is useful over a greater distance than older radio aids, is more accurate, and is reliable in all kinds of weather.

Photo by U. S. Coast Guard

TRANSPORTATION

Reading Unit
No. 12

THE OCEAN HIGHWAY AND ITS TRAFFIC

Note: For basic information not found on this page, consult the general Index, Vol. 15.

For statistical and current facts, consult the Richards Year Book Index.

Interesting Facts Explained

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What America buys from Australia, 10-240
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Things to Think About

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What is "ballast"?
What is a "great circle"?
What trade do the Mediterranean countries carry on with each other?
Where do more than half the people on earth live?
Why does South Africa produce relatively few raw materials?
Why do mail and passenger steamers use the Suez route more than trading vessels do?

Picture Hunt

What kinds of vessels may be seen on the ocean to-day? 10-231, 235, 239
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Summary Statement

The whole network of ocean transportation is much too vast and too complicated for the imagination to grasp, yet on its smooth working our highly geared modern life depends.

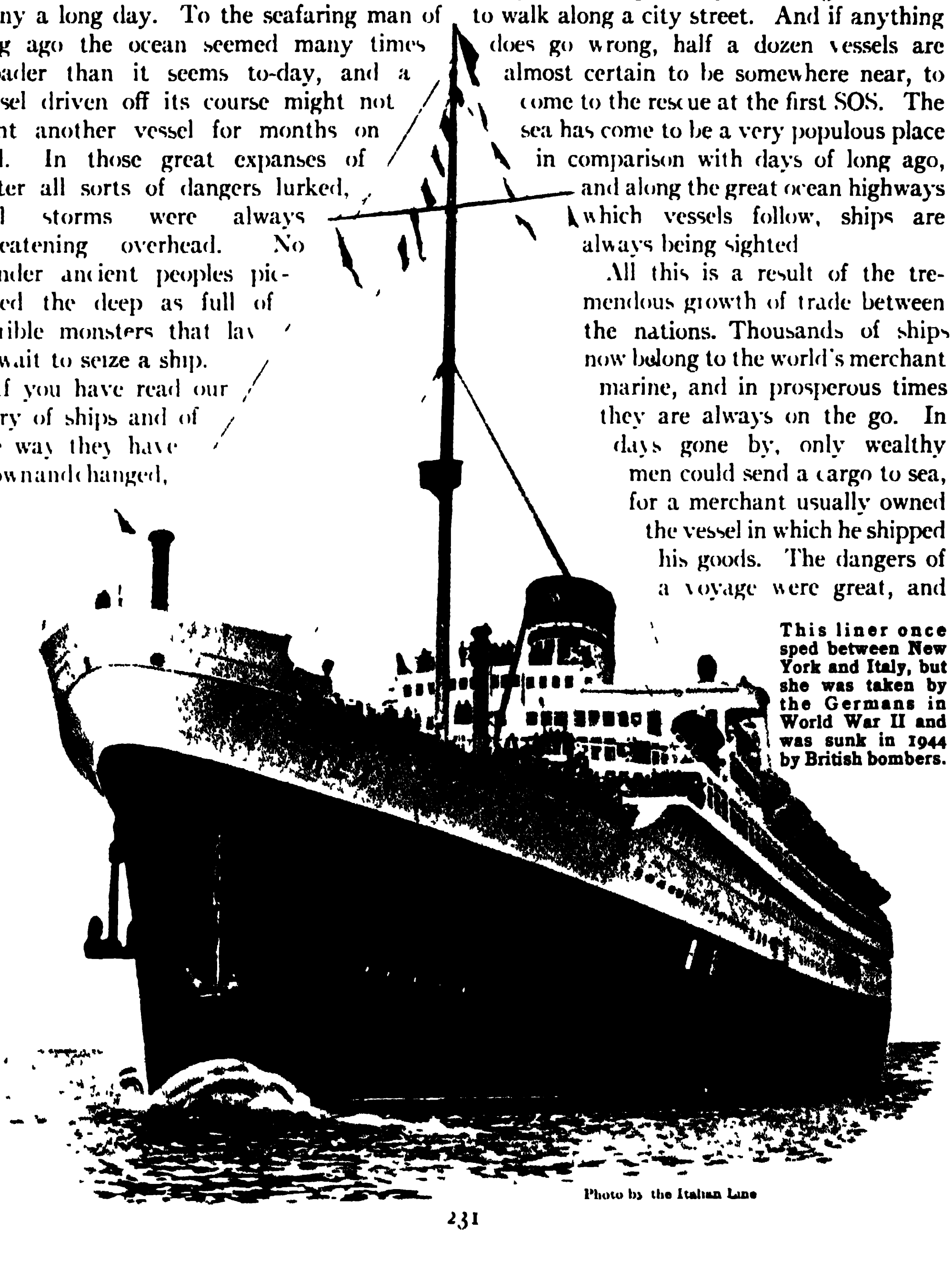
The OCEAN HIGHWAY *and* ITS TRAFFIC

Here You May Read of the Great Lanes of Ocean Travel, of the Cities They Pass, and of All the Amazing Cargoes the Busy Ships Must Carry

"A SAIL! a sail!" And when that cry went up the sailors rushed on deck to hail the first sign of human life in many a long day. To the seafaring man of long ago the ocean seemed many times broader than it seems to-day, and a vessel driven off its course might not sight another vessel for months on end. In those great expanses of water all sorts of dangers lurked, and storms were always threatening overhead. No wonder ancient peoples pictured the deep as full of terrible monsters that lay in wait to seize a ship.

If you have read our story of ships and of the way they have grown and changed, you will know that nowadays an ocean liner is vastly safer than an automobile. To take a trip in one is probably less dangerous than to walk along a city street. And if anything does go wrong, half a dozen vessels are almost certain to be somewhere near, to come to the rescue at the first SOS. The sea has come to be a very populous place in comparison with days of long ago, and along the great ocean highways which vessels follow, ships are always being sighted.

All this is a result of the tremendous growth of trade between the nations. Thousands of ships now belong to the world's merchant marine, and in prosperous times they are always on the go. In days gone by, only wealthy men could send a cargo to sea, for a merchant usually owned the vessel in which he shipped his goods. The dangers of a voyage were great, and



This liner once sped between New York and Italy, but she was taken by the Germans in World War II and was sunk in 1944 by British bombers.

Photo by the Italian Line

the loss was heavy when a boat went down. That fact alone kept people from shipping anything that would not net them a handsome profit.

But nowadays a vessel rarely belongs to the merchant or company that ships goods in it. Shipping is a business in itself. The "liners," which run on schedule and make regular calls at stated ports, belong to large corporations. They are quick and dependable, and carry the mails and small shipments of goods, such as manufactured articles, that would not make up an entire cargo. Their business might be compared to the express service on a railway.

Charter vessels or "tramps" - on the other hand, are hired by a shipper for a single voyage, and nose their way into every corner of the sea, wherever they happen to be sent. Anybody may own one. The owner hires the services of a shipbroker, who from his office in some large port keeps in touch by cable and wireless with shippers all over the world and tells the owner where a profitable cargo may be picked up. Anyone planning to hire the services of a tramp must charter the whole vessel. For this reason the cargo is usually made up of a single bulky article -grain, cotton, coal, ores, petroleum, lumber, sugar, coffee, or some such raw material.

MERCHANT MARINE OF THE WORLD AND OF PRINCIPAL COUNTRIES

(Vessels of 1000 tons and over)

Argentina	99
Belgium	64
Brazil	158
British Empire	2,987
Chile	46
China	195
Dominican Republic	266
Finland	144
France	371
Germany	108
Greece	217
Honduras	56
Italy	245
Japan	268
Latvia	17
Mexico	18
Netherlands	401
Norway	719
Panama	376
Peru	18
Philippines	23
Poland	39
Portugal	72
Spain	264
Sweden	486
Turkey	64
U.S.S.R	417
United States	4,061
Venezuela	35
Yugoslavia	36
Others	102
World total	12,372

This table does not include vessels on inland waterways, channel vessels, icebreakers, cable ships, or those owned by any military force. World War II changed the ranking of countries in merchant fleets. In 1939 the British Empire had almost three times as many merchant ships as the United States.

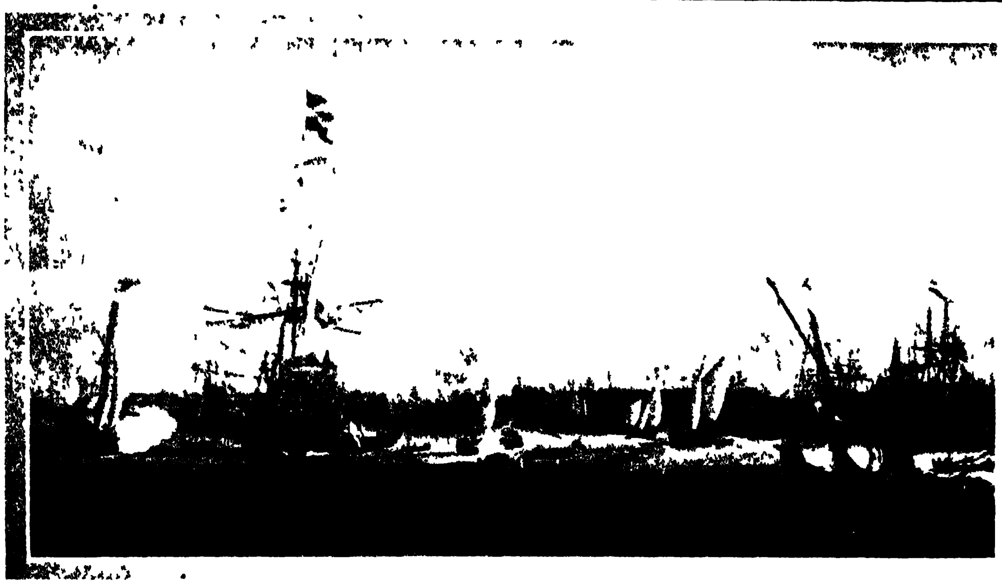
The Easy-going "Tramp"

With goods of this kind speed is not an object. So the tramp can go at a leisurely pace and, unlike a liner, does not have to sail whether she has a cargo or not. There is no need for expensive advertisement to attract trade. She ambles into port whenever she finishes her voyage and sails whenever she is ready. For all these reasons she can carry goods much more cheaply than a liner can. The business of the charter vessels corresponds to the freight service on a railroad.

The coming and going of all the thousands of tramp ships in the world is a very complicated matter. When a ship owner sends out his vessel with a cargo he must think of the return voyage as well as the voyage out. In some ports she will have no trouble finding a cargo, but from others she will have to come back empty or else go out of her way to pick up a load. Part of the cost of chartering a ship depends upon her chances of making a profit on the return voyage.

Then too there is a large seasonal trade to look out for. Canada sends huge quantities of wheat to England after the harvest is over and before the St. Lawrence freezes, but crops in the Argentine grow and ripen during our winter. So it is a great puzzle to dovetail cargoes together, setting one down here, picking up another there, and planning for still a third or fourth before the ship gets back home.

Now it often happens that a region which needs the services of a great many tramp ships to carry away its bulky raw materials—hides or wheat or petroleum- -buys from abroad only the kinds of articles that come on ocean liners. England, for instance, buys raw materials all over the world, but coal is about the only bulky commodity that she can send back in return. Most of her sales abroad consist of manufactured articles, which are shipped on liners. So because vessels sailing to England are eager to have a return cargo, the country exports huge quantities of coal; otherwise



A busy port in Holland looked like this in the days of the white-winged sailing ships While we may regret the passing of those graceful boats that braved so many dangers in strange waters, we must not forget that our own modern ships are much faster and safer and have a romance all their own.

transportation on the cotton and wheat and sugar and hides that she imports would be a good deal higher than it is, and the prices of those necessities would be higher in the English market

What Is "Ballast"?

France is not so lucky as England She has little besides manufactures to send to the countries that sell raw materials For this reason ships often sail from France laden with sand, rock, bricks, or water We say that they go "in ballast" that is, without a cargo, but weighted down with anything heavy enough to make the ship ride steadily. In the past, vessels returning to the United States from France often carried low-priced French wine as ballast.

On other pages we have told of the great strides made in shipbuilding in the course of the centuries, and of all the graceful and compact craft, from ore boats to tankers, which have been invented to carry the world's goods. Every great port will show an amazing variety of them. Though they have lost their white wings of days gone by, they still are graceful as well as serviceable, and are vastly safer than in the olden days. It is not only that they have improved in construction The old wooden vessels have given way to steel ones, until to-day fire, once the sailor's worst enemy, has been largely robbed of its terrors Lately shipyards in the United States have turned out vessels that are ninety-nine percent unburnable Our government requires that not more than ten percent of the material in new vessels shall be of wood

And where do they mostly go— these great floating warehouses that play so big a part in our modern life? Large numbers of them are to be found plying back and forth across the North Atlantic That is the world's greatest highway of ocean trade Canada, the United States, Mexico, and the West Indies, all are within easy reach of the great ocean lane which connects the New World with Northern Europe

A Simple Rule for Ocean Pilots

At first it may seem strange that boats from Quebec and Havana should take almost the same path in going to England, but a globe will make the reason plain, as a flat map cannot. The shortest distance between any two points on the earth's surface lies along what we call a "great circle." A great circle is merely an imaginary line drawn

around the earth in such a way that it divides the earth into two equal halves. The Equator is a great circle, for instance. Of course you may draw one through any two points on the earth's surface.

The Shortest Way to Europe

Now a great circle from New York to Southampton would pass over New England and the eastern end of Canada. Naturally ships leaving New York sail east till they get out to sea, but then they bear to the north until they reach this imaginary line, which they follow the rest of the way. Because the eastern coast of North America does not lie straight north and south, but slants from northeast to southwest, it extends in general along the path of the great circle of which we have been speaking. As a result, ships leaving any of the ports along the eastern coast and the Gulf find themselves following the same great ocean highway. That is why any ship sailing along the beaten path between New York and Southampton sights other vessels all along the way.

For the same reason merchants of the West Indies and along the Caribbean Sea are not sending goods much out of their way when they ship merchandise to New York for reloading to one of the great liners that sail regularly to Northern Europe. Goods are sent back by the same route

Dangerous Spots along Our Coast

In winter ships follow a path somewhat to the south of the summer route. And at that time of year, when the St. Lawrence is frozen, Montreal stops her shipments to Europe and Canadian wares go overland to the ports of Halifax, St. Johns, Boston, and New York. At all times vessels bear well out to sea in passing Cape Hatteras, on the coast of North Carolina, or treacherous Sable Island, off the coast of Maine; and they give a wide berth to certain rocks on the Grand Banks of Newfoundland. In those fog-infested waters many little fishing boats are always coming to a tragic end, and many larger vessels go to their graves when they encounter the icebergs that come floating down in summer.

Nor is the voyage always tranquil. The North Atlantic route lies in the path of the boisterous west winds, which used to deal roughly with a ship before the days of steam. Often sailing vessels, though they were glad enough to have those winds to blow them eastward, refused the combat when it came to sailing in the opposite direction. They went south to the Canary Islands, and from there across and up our eastern coast.

The Ocean's Busiest Highway

But it takes greater terrors than the ones we have mentioned, to stop the flow of trade. Along this famous highway ply the finest ships mankind has ever seen, luxurious liners that link the world's two greatest democracies, the richest countries on earth. Here too has passed that vast army of emigrants who in the past three hundred years have peopled our continent. To-day they do not come in such great numbers, but travel is heavy, just the same. Most of the important manufacturing nations lie within reach of this great ocean route, which has the heaviest freight and passenger traffic of any in the world. London, Liverpool, Southampton, Bristol, Glasgow, Hull, and Newcastle, Havre (ä'vr'), Bordeaux, and Cherbourg (shĕr'bōōr'); Antwerp, Amsterdam, and Rotterdam; Hamburg, Bremen, and Stettin, Copenhagen, Danzig (dan'tsiK), Riga (rē'gä), Leningrad, Stockholm, and Oslo (ŏs'lō) ships from all these ports use the same great path to reach the bustling nations of the New World.

The North Atlantic is not the only busy part of that much traveled ocean New York, the world's greatest port, sends out ships in many directions. Large numbers sail to the Mediterranean, and many go on east to the Orient by way of the Suez (sōō-ĕz') Canal. For this too is a great trade route. It goes through the oldest and most populous part of the world, and carries goods for over three-fourths of the earth's inhabitants.

Of course much of the trade along this ancient ocean highway does not go the whole length of the way. There is, for instance, our own trade with countries in the Mediterranean Time was when most of the goods we got from them were sent to London or Liverpool and reloaded there. To-day a

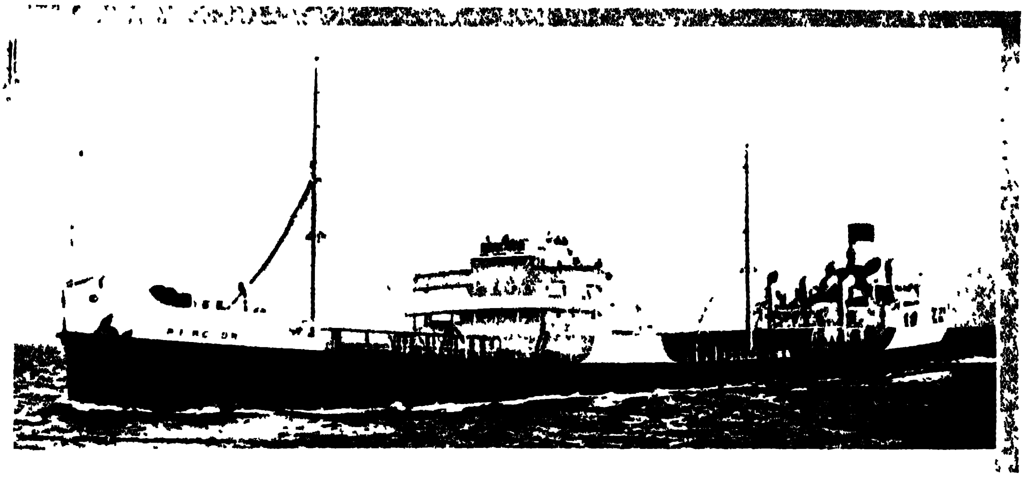


Photo by the Standard Oil Co

If you have lived at all upon the water, you will have seen many an oil tanker like the one above. You may well have learned to tell who her owners are by the color of the stripes on her funnel. Oil tankers are built to lie efficiently low in the water. When not loaded they carry heavy ballast.

number of regular steamship lines connect New York with various Mediterranean ports and bring back olive and other vegetable oils, fine leather goods, china, silks and linens, and many other manufactured articles in return for the foodstuffs those countries must buy from us to help feed their crowded populations. There even are lines uniting us with Constantinople and the Black Sea, for the agricultural lands along the Danube and around the Black Sea are glad to get our farm machinery.

Of course the countries on the Mediterranean carry on a lively trade with one another. Italy, France, and Spain are all crowded nations that have to import food. They can get it from Northern Africa and the lands around the Black Sea and along the Danube. Grain, fruits, and poultry products are exchanged for the manufactures that the more crowded countries produce. The Black Sea region also has ores and petroleum to sell.

What Is Africa's Busiest Port?

Northern Europe naturally does a thriving business with the warmer lands farther south. Early vegetables go from Northern Africa to Paris and London, often by way of Marseilles, which also gets African olives, wine, wool, and wheat. Alexandria, at the mouth of the Nile, is Africa's busiest port. That great continent has no very good means of getting her rich resources to the sea, and so she has many little harbors but few big ones.

Strange Wares from the Orient

Of course there is a heavy traffic between all the countries of the West and those of the Orient. It is very old indeed, for almost as soon as history began, the people of Egypt wanted the fascinating wares that came from the East. In those days long caravan trains carried a few valuable products overland to the Mediterranean shores. Those difficult and dangerous routes are still in use to-day, but with the opening of the Suez Canal (1869) they lost much of their traffic to ships, which can carry the goods more easily and cheaply. At one time vessels carried the trade the whole distance except across the Isthmus of Suez, where caravans took the goods overland. Because the Far East had little interest in the wares the West had to offer, gold and silver were, for the most part, the products sent back in exchange.

But now all this is changed. The Western nations are turning longing eyes toward the rich markets still to be opened up in the crowded lands of the East. Half the people in the world live in India, China, Southeastern Asia, and Japan. Most of them are very poor, and barely keep body and soul together by tilling a tiny piece of ground.

But they are skillful and artistic races, making many beautiful things by hand; and China, at least, is one of the richest nations in the world in mineral resources. Her people are beginning to awaken, as the Japanese have already done, and some day will come into the complicated life of the Machine Age. Then they will need all sorts of Western products, and will have the money to buy them.

Wares for Sale in Modern China

So there is keen rivalry among the Western nations to gain a foothold in those future markets. Before World War II the Chinese bought large quantities of rice, cotton goods, machinery, metals, tobacco, kerosene, and many manufactured articles. In exchange they sold raw silk, soybeans, oils for making paint and varnish, raw cotton, tea, and various manufactured wares. Their best customer for raw materials was Japan.

Japan has been a great trader. With the exception of parts of China, her inhabited areas are more crowded than any on earth. This of course means that she cannot export food. What land she has must, if possible, go to raising crops the people can eat. And even then the Japanese diet is a miserable one. Western peoples could never live on it. In raw materials Japan is hardly better off than she is for space. She has no iron and very little coal. Yet before World War II she was using huge quantities of iron to build up the navy with which she fondly hoped to conquer the world. So what has she done in order to buy the things she got from other countries? Her exports of silk and tea have come far short of paying the bill.

There has been only one way open to Japan. It was to turn her clever, obedient people to manufacturing goods that could be exchanged for all the many things she needs from the rest of the world. So she has rapidly gone into industry. She has made all sorts of wares—china and paper products and various novelties—which she can sell cheaply in the West. Particularly she has developed the manufacture of coarse cotton goods, which she can set down in India and the Philippines more cheaply than England and the United States càn. She has not room to grow much cotton herself, but she imports it from the United States, China, and India. For the people of India, crowded though they are, have not yet awakened to the value of manufactures, and so do not weave much of the cotton that they grow.

In view of all these facts it is not strange that the Suez highway, the most direct route between Europe and the East, should be crowded with ships. For a long time we got our own imports from the Far East by way of London. But since the opening of the century we have had lines going direct to various Asiatic ports. We send them our cotton, petroleum, machinery, tobacco, wood, iron and steel products, textiles, and dyes.

When a Tramp Sails around the World

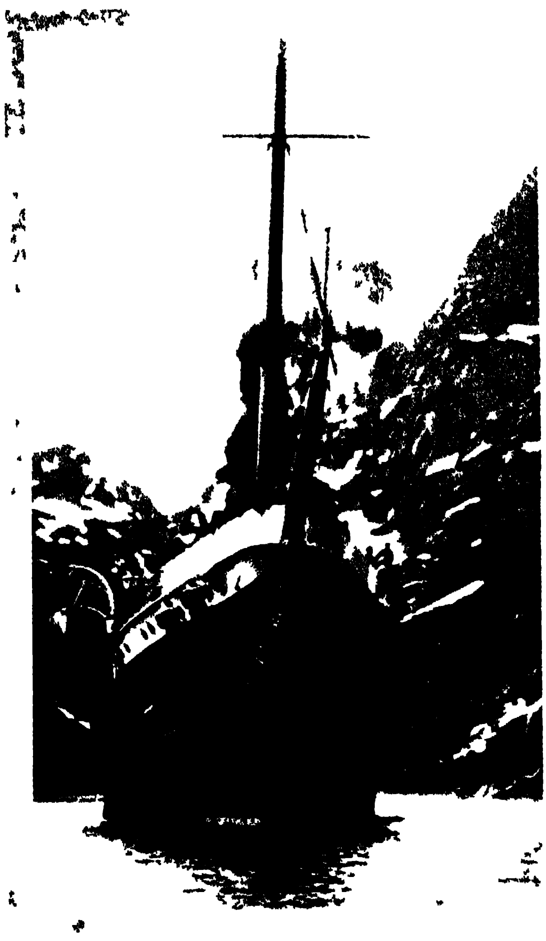
As it happens, the return cargo is a good deal less bulky, for the Far East—and especially China and Japan—does not ship us many raw materials. So charter vessels, both from America and from Europe, often have to look about for a handy return cargo. They may be able to pick up a load of sugar in Java, of hemp in the Philippines, of rubber or tin in Singapore, or of rice at Rangoon (răng-gōōn′), in Burma. Often the tramp steamers sail back home by way of the Pacific and Panama. Many of them go out loaded with oil from the refineries along the Atlantic. After they have delivered it they pick up a cargo of lumber at Puget (pū′jĕt) Sound and come on home by way of the Canal. They have sailed around the world. English steamers, too, often cross the Pacific and get a cargo here to take on home.

Of course the trade between Europe and the East is much greater than our own. England, for instance, exchanges all sorts of goods with Eastern sections of the British empire. Together with other countries of Western Europe she sends out machinery, iron rails, locomotives, cotton goods, clothing, canned goods, and a vast quantity of other manufactured articles.

In return the East sends back to the West a bewildering list of wares. China and Japan export raw silk and tea; the Philippines, sugar, Manila hemp, copra, and coconut oil.

Java too has sugar to sell, and Singapore, (sĭng'ga pôr'), the world's greatest rubber port, handles tin and spices besides. Rice is the great export of the small countries of Southeastern Asia, for they are the only ones in the world that have a large surplus. In the West London and Bremen have been the cities that chiefly handled it.

India sells the West tea, and jute from the valley of the Ganges (găn'jēz) River. Calcutta is the port which ships the jute and Dundee in Scotland has for more than a century been the center for its manufacture. Linen weavers there took up the industry when hemp began to fail them. Today their gunny sacks go all over the world. Calcutta's tea export is shared with Colombo (kō lŏm'bō), on the island of Ceylon (sē lŏn'). At Bombay (bŏm bā') on India's western coast, a tramp steamer can pick up a cargo of wheat or cotton or oil seeds and at Karachi (ka rä'chē) in Western Pakistan, it can find grain from the valley of the Indus (ĭn'dŭs). If all these fail the Persian Gulf may give it a cargo of dates, oil, hides, wool, or oriental rugs. Basra (bŭs'ra), about seventy miles upstream from the coast, is the port for Baghdad (băg'dăd) and is the world's chief date center. The finest dates grown come from the region round about.



The steamer in the photograph has found her way into a fjord one of those magnificent drowned valleys that indent the rocky coast of Norway. After the valleys were gouged out by glaciers the land sank and the sea came in. So to day the fjords make fine shelters for many of the smaller boats.

Of course the countries at the eastern end of the Suez route exchange goods among themselves, for the ones in the tropics have many wares that those farther north want to buy. So India, Burma, Indo China, and the East Indian islands do a good business with China and Japan in cotton, rice, and sugar. In return they get from Japan cotton goods and other manufactured articles, and a certain amount of coal.

As we have seen, this great world highway to the East splits at its western end in order to communicate with Northern Europe and with the United States. At its eastern end also it divides that China and Japan to the north, and Australia to the south may all be served. Like the North Atlantic route it has plenty of coal at the two ends—in America, Great Britain, Australia, and Japan. But it is very long, and through much of its length, for instance, in the Mediterranean, there is almost no coal at all. For the benefit of ships coaling stations have been set up—particularly at Gibraltar, Algiers, Port Said (sä ēd'), Aden (ä'dĕn), Colombo, Singapore, Hongkong, Shanghai, and Yokohama. Singapore is especially important, for the British fortified it heavily before World War II and made it a great naval base to protect territory in the East. It owes its

existence as a great world port entirely to the growth of the important East-West highway which we have been describing.

What Governs the Price of Coal?

The price of coal at the various ports along this great route depends much less on a port's distance from a coal field than on its nearness to a district that is likely to furnish the freighter with a good cargo for the return voyage. If transport rates happen to be low—and they vary greatly the cost of stopping at a port will make it cheaper to carry a small cargo and a large supply of coal. But if rates are high, it will be better to carry a big cargo and stop often for coal.

The oldest of all the ocean routes to the East is the one around the Cape of Good Hope, the southernmost point in Africa. On other pages we have told something of its early history, which began centuries before the Suez Canal opened up the great route through the Mediterranean. To-day the older route is much less used, not only because it is longer, but also because it serves fewer great markets along the way. For Africa is far less developed in agriculture and manufactures than Europe and Asia are.

Goods from "Afric's Burning Shore"

Both America and Europe send liners to Cape Town and to two or three neighboring towns, and a number of lines go from European cities down to the little harbors along the west coast, where they pick up ivory, palm oil, palm nuts, peanuts, rubber, mahogany logs, and cacao. In return the traders sell their black customers acres of cotton cloth, various kinds of food stuffs, and a certain number of other manufactured articles which the simple natives have learned to want. Down the east coast, too, come steamship lines from a number of European countries. They pick up rubber, hides, copra, spices, and copper at various little ports, and leave food stuffs, metals, liquors, and the cotton cloth which all tropical countries use in such large amounts.

The white men of British South Africa have a great many more wants than the black men farther north. Unlike most new and sparsely settled lands- such as Argentina and Australia South Africa does not produce a great many raw materials. For one thing, she has too little rain to make farming pay well. But more than that, she gives much of her time to the mining of gold and diamonds. These are what she gives the world in exchange for the grain, flour, lumber, machinery, clothing, foodstuffs, iron and steel, and all the varied manufactures that white men want. To be sure, she has other products and is glad to sell them. Her plains are not too dry for grass to grow. So Cape Town and the small cities near it on the eastern coast are centers for shipping a certain amount of wool, mohair, hides, skins, and ostrich feathers, which come down from the interior. And copper too is loaded there.

The Traffic round "the Cape"

Now it will be easy to see that no merchant is likely to ship very big cargoes of gold or diamonds or ostrich feathers. What is a vessel to do after it has discharged its load of American wheat or English woolens? It must look about elsewhere for a cargo to carry home. So some go farther east to pick up rice or grain or cotton or jute or sugar. And some cross over to South America to get a cargo of grain or wool at Buenos Aires (bwä'nōs ī'räs), and then sail home again.

After rounding the Cape of Good Hope a ship sailing from London or New York has three paths open before it. If it takes the one to the left it can coast up the eastern side of Africa. The center path leads to India and beyond, and this is the one taken by sailing vessels that carry refined oil to India and China and Japan. But the great bulk of the traffic around the Cape takes the path to the right and goes to Australia. For most of the world's traffic with Australia goes by this southerly route. The Suez route, though a thousand miles shorter, is more expensive, and so is used mostly by mail and passenger steamers.

It is a romantic procession that rounds the Cape for Australia. Here, of all places in the world, you may see the sailing vessels

Photo by the Dollar S S C

This vessel is taking on cargo in New York, the world's greatest port Dockhands are busily rolling out boxes from the warehouse One such box is already being hoisted up the side of the boat by means of a cargo boom, or derrick Notice the cargo nets that have been hung to prevent any of the boxes from falling into the water The disk-shaped object at the left is a guard to keep rats from climbing aboard

as they were in days gone by for the route around the Cape is the one where they can best compete with steam On other pages we have described the boisterous west winds that sweep across the vast stretches of open sea in these latitudes Those are the winds the sailors love Once the Cape is left behind, the breeze will carry a stout ship through the roaring forties all the way across the Indian Ocean to Australia or New Zealand, with never a pause Steamships must take on enough coal in South Africa to last them clear to Australia but a sailing vessel can fill her hold with freight and scud along without a thought of fuel She offers the cheapest transportation to be had

How to Sail across "the Trades"

On many other routes her problem is not so simple She must try to go at right angles to the trade winds, which, as we have explained elsewhere, blow toward the Equator from northeast to southwest in the Northern Hemisphere and from southeast to northwest in the Southern Hemisphere This makes it necessary for a sailing vessel leaving New York to follow a zigzag course in order to reach Cape Town First she sails east with the westerly winds that blow across the Northern Hemisphere Then she turns into the trade winds and crosses them as she sails southward When she reaches the westerly winds of the Southern Hemisphere she turns to the east again and so rounds the Cape Going back she cannot take advantage of the westerlies and so steers a straighter course

Which Way Is the Wind?

All sailing vessels must fit their courses to the paths of the winds in just this way, and for that reason they often follow quite a different route from that of the steamships, which try to take the shortest way The fact that a sailing vessel may have to cover more miles is of slight importance to her She spends no money for fuel, so distance does not count She searches out the course upon which the winds will send her along with the greatest speed, and is glad to escape a short route on which she is likely to find herself becalmed

For this reason it is easy to see why, once having reached Australia, a schooner will often keep on east across the Pacific and then turn north across the trade winds to go to San Francisco or Panama. Or if she is bound for London, she will round stormy Cape Horn, at the southern tip of South America, and then turn north across the trades until she reaches the west winds of the Northern Hemisphere. No sailing vessel tries to go westward past Cape Horn if she can help it. At times the winds are so strong there that the feat is utterly impossible.

Photo by Comm Standard Oil Co. (N J)

This giant tanker plies the ocean regularly between Texas and New York. Here it is taking on its cargo of oil at Corpus Christi, noted for petroleum exports.

Ships going out to Australia carry cotton and woolen goods, machinery, lumber, wood, and a great many manufactured articles, for Australia is a thinly settled country with a great deal of dry land suited only to pasturage. She does not manufacture much. But she has plenty of things to sell. England buys from her large quantities of wheat, butter, frozen meat, hides and skins, a certain amount of gold and copper, and, above all, wool, which is the country's leading export. New Zealand too sends the mother country these same wares, and large quantities of dairy products, of which she exports more than any country in the world, for she has more grass than Australia.

Cargoes Back from Australia

At times vessels reaching Australia have to hunt about for a cargo, but they can always fall back on Australian coal to take to ports in the East Indies or to Hawaii, where sugar is to be had, or even to San Francisco, where a variety of wares can be taken on, once the coal is unloaded. Chile, too, is willing to take coal in exchange for nitrate of soda.

Vessels from the United States are very likely to have to search for a cargo on reaching Australia, for though we send her a great deal of goods by way of the Cape route, about all we buy from Australia is wool, and that is handled by the London markets. Lumber, machinery especially such as may be used for farming iron and steel manufactures, leather goods, and a host of other articles that our factories turn out are all in demand in Australia. But once they have been delivered, the ships that carried them must look elsewhere for business.

From what we have said it will be plain that there is not much trade directly east and west across the South Atlantic and the South Pacific The reason is plain The countries bordering on those seas are all relatively new, and are in the same stage of industrial development. Their climates too are about alike. For these reasons the products are similar and there is no particular reason for exchanging them What those countries do want is the produce of the tropical lands farther north and of the manufacturing countries of the Northern Hemisphere. They want textiles from England and machinery from the United States. So the ships that visit the Southern Hemisphere come down from the north, for the most part, and go back north when they sail.

Routes to South America

South America is visited by a great many lines and tramp ships coming from Europe and North America. Some of them skirt the shores of the Caribbean, taking in the

West Indies on the way. In exchange for machinery and every sort of manufactured article they take home the produce of those tropical lands coffee, gold, and platinum from Colombia; asphalt and petroleum from Venezuela; cacao, sugar, petroleum, and asphalt from Trinidad; and bananas and other fruits from a good many places.

Trolley Cars by Muleback

Because South America has no good systems of inland transportation she has few large ports where goods are gathered for shipment. Instead, ships must stop at dozens of little ports along the coast, where short trade routes have brought down wares produced a little way back from the sea. Often on the western coast these goods have come over perilous trails on the backs of mules and the automobiles and trolley cars that the ships bring in must go back over the trails in the same laborious way!

The great Amazon River in Brazil is of tremendous service on this very account. It flows through the rubber country and carries rubber, Brazil nuts, and cacao to ocean vessels at Manaos (ma-nä'ōs), 860 miles from the river's mouth, and to Para (pa-ra'), on the coast. Bahia (ba-ē'a) and Pernambuco (pûr'nam-bū'kō) serve a tropical region that sells sugar, cotton, tobacco, cacao, and hides

The Great Coffee Ports

But Brazil's great ports are Rio de Janiero (rē'ō dā zhä-na'rō) and Santos (san'tozh). They are the ones that ship the vast quantities of coffee which make up the country's leading export. Naturally, since the United States is a coffee-drinking nation, we take large quantities of it from Brazil. And we sell her machinery and other goods, though she buys a great deal in the way of manufactures from Europe. So what regularly happens is that ships leave Europe loaded with coal, cotton cloth, machinery, and other manufactured products, which they exchange in Brazil for cargoes of coffee to take to the United States. And since Europe is always eager for our farm products and certain kinds of machinery, the ships go on back to their starting point with loads of wheat or lumber or farm machinery. Southern Brazil has of late years been exporting more and more oil seeds, frozen meat, and mate (mä'tā), a kind of tea. Since the outbreak of World War II Brazil's trade with the United States has grown very fast.

Buenos Aires, in Argentina, gets produce carried down to her by the Plata (pla'ta) River, and has become the leading city in South America. Because she serves new countries in the Temperate Zone she ships vast quantities of grain and meat, as well as hides and other animal products. She gets back much the same commodities as Brazil many of them less bulky than the ones she ships. So it often happens that the boats which carry away her bulky products are those which have come over from South Africa, where they unloaded a cargo without being able to pick up one to take home.

The Nitrate Ports

Along the west coast of South America the ports are all small, though in Chile Iquique (ē-kē'kā), at the end of a short railroad leading into the nitrate district, has quite a trade, and Antofagasta (an'tō-fa-gas'ta) ships nitrate and large quantities of copper, as well as silver and other ores. Chile's nitrate trade has fallen off greatly of late, since chemists have learned to get nitrate easily from the air. Besides the products we have mentioned she sells the world iron and iodine. We have already said that many of the vessels that carry away nitrates from Chile and ores from all along the coast have come across the Pacific with coal from Australia. They go north and pass through the Panama Canal.

West to the Far East

We have left till the last the story of a route that is comparatively new but that is growing fast in importance. It reaches across the North Pacific, and connects North America with Eastern Asia. By way of the Panama Canal it joins the busy trade of the Atlantic. More and more goods pass over it, as we exchange larger and larger amounts of raw cotton, iron, lumber, machinery, foodstuffs, and petroleum for silk, drugs, tung and other oils, tea, and various curios.

Those things that we sell the Orient take up a good deal more room in ships than do the things we buy, so many vessels from the Atlantic– most of them carrying oil come back to our own west coast in ballast and there pick up grain to carry on home. Vancouver (văn-kōō'vĕr), Seattle, Portland, San Francisco, and Los Angeles, all send out numerous cargoes every year. European vessels are likely, as we have said, to go to the Far East by way of Suez and then sail on home across the Pacific and through the Canal. They always can find a cargo somewhere in North America, for the continent produces a great many important raw materials.

Some Surprises in Direction

Unless you have a globe beside you it will probably be a surprise to you to learn that ships sail to China and Japan by going, not west, but north. For the Pacific is so wide that the great-circle route between San Francisco and Yokohama (yō'kō-hä'mä) the great Japanese port at which nearly all ships stop would skirt the Aleutian (ȧ-lū'-shăn) Islands, off the coast of Alaska. It is even more surprising to learn that a line of airplanes following the shortest route between the Panama Canal and Canton, the great city of Southern China, would undoubtedly stop for mail and fuel at Detroit or Chicago. Surprises like these show how greatly the flat maps we see on a printed page may deceive us.

Once arrived at Yokohama, an important coaling station, a ship has only to keep straight ahead to reach the great ports of Shanghai (shăng'hä'ī) and Hongkong in China. Since the Japanese earthquake of 1923, Kobe (kō'bĕ), in Western Japan, has also been doing a lively trade. Manila, in the Philippines, lies at the end of this long route.

What Do We Get from Alaska?

By bearing off a little to the right on leaving San Francisco or Puget Sound a vessel will reach Alaska, with its ports at Sitka, Juneau, Skagway, and Seward. That picturesque land needs the machinery, foodstuffs, and countless manufactured articles that a new country cannot supply for itself. Its mining and fishing industries and its fur trade supply goods to send in exchange. And most of those valuable wares must go by ship, for there is no railroad out.

A ship sailing to Hawaii will have to keep well to the left and sail far south of the main northern route. But many vessels make the journey, for Honolulu ships large quantities of sugar, pineapples, and other fruits to exchange for all the foodstuffs and manufactured goods that she gets from the United States by way of San Francisco. And of course many ships will stop at Honolulu on their way to Southwest Pacific ports.

Steamships on the North Pacific must carry coal all the way between the North American ports and Yokohama. San Francisco has none very near, but she imports it, as we have said, from both Japan and Australia, in ships that would otherwise have to cross the Pacific in ballast. At the other end Japan has a good supply for ships setting sail.

Sails on the Pacific

Traffic in these northern waters has developed since the middle of the nineteenth century, and therefore since the day of sailing vessels. But white wings still scour the Pacific. Coming eastward they take advantage of the brisk westerly winds that blow in the neighborhood of the fortieth parallel. Going westward they turn farther south and take advantage of the northeast trade winds. In both the Atlantic and Pacific, sailing vessels dread the zone of calms that lies in the neighborhood of the Equator.

The Branches on the Tree

Now of course the great ocean highways that we have been describing are the trunk lines from which countless branch lines spring –coasting vessels, ships plying between islands or ports on inland seas, river traffic that brings down products to the world's great market routes. Ports gather the wares together and ship them off across the world. The whole network of transportation is something too vast and too complicated for the imagination to grasp. Yet on its smooth working our highly geared modern life depends.

Reading Unit No. 13

THE BUSY ROMANCE OF THE HARBOR

Note: For basic information not found on this page, consult the general Index, Vol. 15. *For statistical and current facts, consult the Richards Year Book Index.*

Interesting Facts Explained

Why a port is of tremendous importance, 10–245
How ships were protected from pirates, 10 245
Famous river ports, 10–246
How a port of entry depends upon markets, 10-246-47
New York City, the world's greatest port, 10-247-48
Why the loading of a vessel is a science as well as an art, 10 248-49
How far New York City's waterfront extends, 10–250
The agencies that control the seaports, 10 250

Things to Think About

Why did the docking of a ship cause great excitement in days gone by?
Where is the romance to be found in the seaport of to-day?
Why did Paris lose her commercial importance while London kept hers?
Which are the world's finest harbors?
What is the difference between an "overside" and a "quay" port?
Why must the handling of freight be supervised?

Related Material

Where did the pirates hide the gold they stole from the Spanish treasure ships? 7–51
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How fast could some of the famous clipper ships travel? 10–172-73
Where do the ferryboats take the freight cars that come across New Jersey to the Hudson River? 10–198

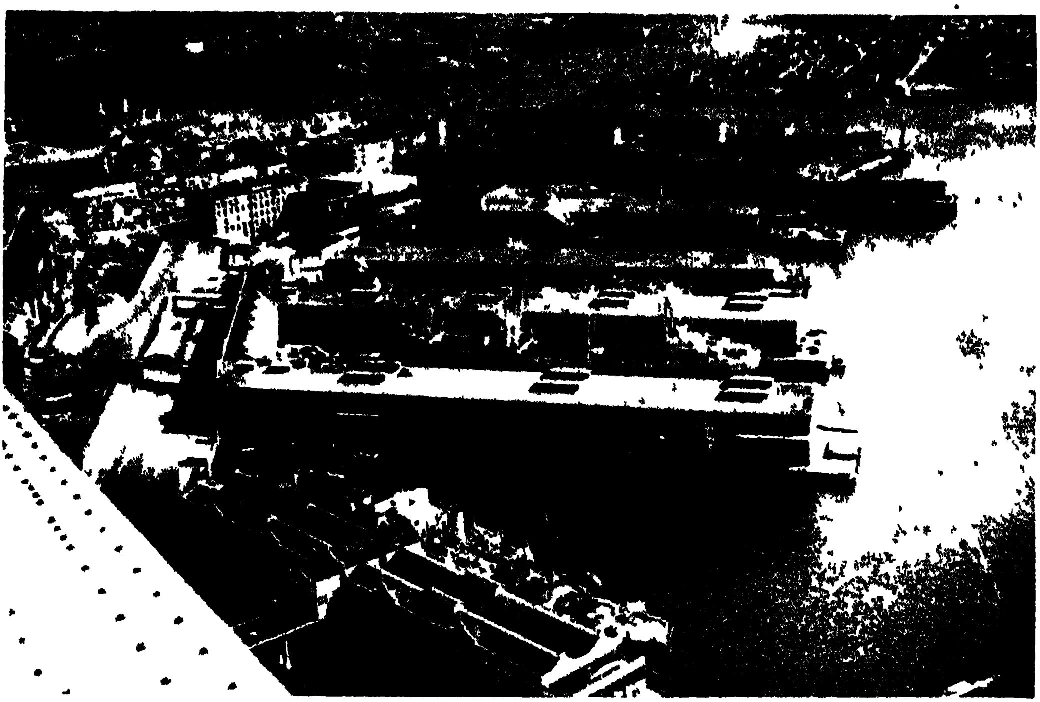
Leisure-time Activities

PROJECT NO. 1: Make a model of a lighthouse, 14–34

PROJECT NO 2: Memorize John Masefield's poem "Cargoes."

Summary Statement

Although the Machine Age has made it very complicated, the modern seaport is one of the busiest and most efficient places in the world— of the greatest importance to a nation's prosperity.



Australian News and Information Service

Sydney's magnificent natural harbor has turned the tiny pioneer settlement of 1788 into a great commercial port which handles most of Australia's exports It was a major supply base in World War II

The BUSY ROMANCE *of the* HARBOR

Seated between the Sea and Land and Giving a Hand to Each, a Great Harbor Links Nation to Nation and Race to Race. Our Busy Modern Life would be Impossible without Our Ports and Their Equipment of Docks and Terminals.

GRACEFULLY, majestically with many a warning toot for the smaller craft swarming about her, the great ship steams slowly into the harbor Once more she has made the voyage over thousands of miles of sea, bearing her precious cargo of freight and lives She has taken on the pilot whose business it is to guide her among the ever shifting sand bars which, in spite of dredgers kept constantly at work, always lie in wait to trap a heedless vessel As she nears her "berth" the place where she will dock her engines are silenced and a flock of little tugboats, sounding shrill, self-important whistles, steam up to tow her the rest of the way and "warp" her to her pier They push and pull and nose and shove her into the narrow slip, for they are quick and lusty and are handled with amazing skill Even then they may miscalculate, and the great vessel, powerless to manoeuver in so small a space, may take off the end of the dock before she comes to rest

But our ocean liner is not the only vessel to come to port to day A bevy of pretty yachts, a five masted schooner sailing from Cape Cod way, a half-dozen sober freighters, tankers, a battered tramp or so, all have business here and all find a comfortable spot to go to bed after their journey The shores are lined with wharves where dozens of boats are already tied, waiting for loading or unloading The water front is a forest of spars and funnels

No wonder we can idle here by the hour, watching the feverish bustle, listening to the shouts of the men who manage the cranes, sniffing the tang of sea and tar and the dusty odor of the cargoes. We shall hear every language under the sun, and see the flags of all the world's great seafaring nations. To be sure, the docking of a ship does not create the excitement to-day that it caused in days gone by, when all the people of the town came thronging to the shore to get news from across the sea and to glimpse strange wares from other lands and climes. To-day the larger seaports are great bustling cities with a busy life of their own, and much of the old romance is gone for many people.

But not to those who understand the driving energy and the gigantic problems of our modern day! Our thronging commerce has crowded into the great ports until they stretch for miles along the water front, with docks, piers, and warehouses of vast size. There are huge machines to do all sorts of jobs—gigantic cranes and derricks, winches and windlasses, moving platforms and conveyors, electric trucks, railways, tugboats—and a small army of men who work at special trades. A modern port is one of the busiest and most efficient places in the world and very complicated. Days would be needed to see it all.

Photo by P. I. Bureau of Agriculture

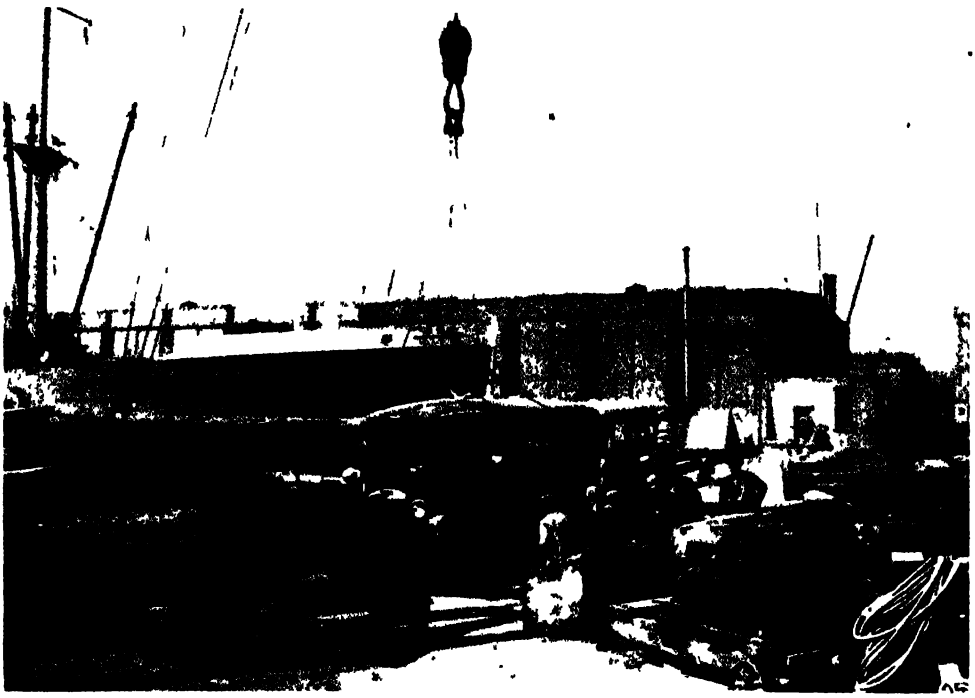
Once all the shipping of the world came to port in harbors as primitive as this one at Manila, in the Philippine Islands. Today the quaint native craft are giving way before the ocean giants that crowd the great world ports and as a result, you and I, and the people of Manila as well, may have the wares of every land the sun shines on.

Now a port, whether it lie on the shore of an ocean, lake, or river, is really only a harbor. It includes the water area where the vessels lie while loading and unloading, and the land area where goods are stored to await the sailing of a vessel or are held until they can be sent on to their final destination by truck or train, by coastwise or river steamer. A port is merely a link in a vast transportation system that reaches out over the whole world. As such, it is of tremendous importance in the commercial life of a nation—of all nations. The well-being of farmers and miners, of factory workers, business men, and bankers, depends upon the way a nation's ports handle their tasks.

Practically every great port in the world lies either at or near the point where a river empties into an ocean or lake. In earlier times ports usually lay a considerable distance above the river's mouth, so that shipping would be safe from pirates raids. In those days the small sea-going vessels could easily make their way up the shallow river channels. But when men began to build vessels of deeper draft—that is, vessels so large that thirty or forty feet of water is necessary to float them—river ports that had earlier been great centers of foreign trade either lost much of their business or in some cases went out of existence altogether. Such was the fate of Paris, of Cologne (kō-lōn′) in Germany; and of Bruges (bruzh) in Belgium. All saw most of their trade slip away. Various other ports—among them London in England, Hamburg and Bremen (brĕm′ĕn) in Germany, Antwerp in Belgium, and Bordeaux (bôr′dō′) in France—were able to widen and deepen the river channels that led to their docks and so kept their commercial importance. Of late Paris too has regained her old trade.

The Greatest Natural Harbors

The very first requirement of any port is that it be able to shelter ships from a storm. Usually the river or bay where the port is located gives a natural shelter. New York, San Francisco, Sydney in Australia, and Hongkong in China are the world's finest natural harbors. But there are other ports, most of them on rivers, where great engineer-



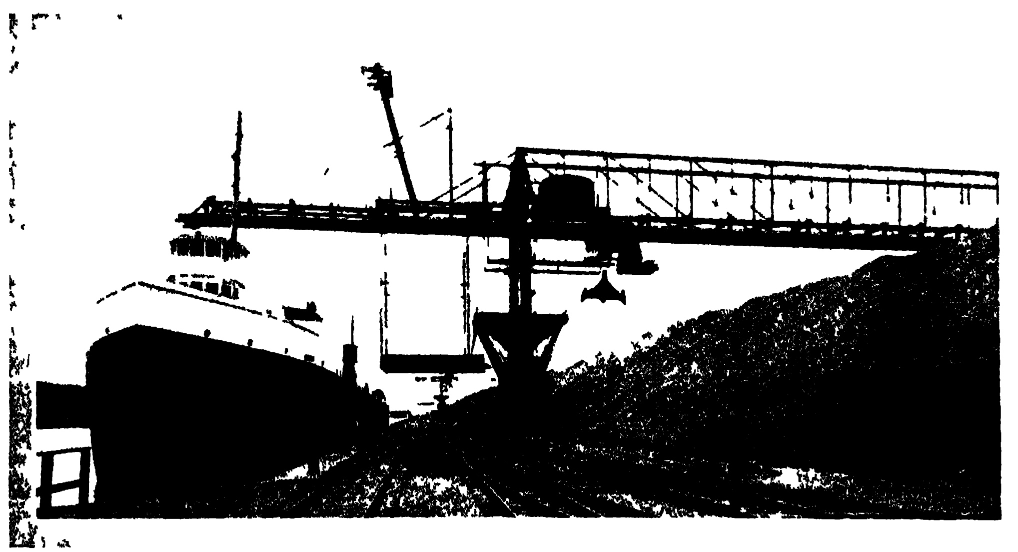
The longshoremen in this picture are not working very hard, for they know that the dockside crane will load their huge autobus on the freighter in a few minutes, without much help from human hands. These cranes make the loading of baggage and freight a simple matter, and enable ocean liners to make a quick turnabout.

ing works known as breakwaters have been built in order to give vessels a safe berth. Some of these ports include tidal basins and piers, and locks. By these means ships are kept afloat within certain areas when the tide is low. Liverpool has such a huge dock works. The tide there rises and falls some twenty-five or thirty feet, and as a consequence large vessels must come in at high tide, enter a basin, stay locked there at a permanent water level while they are held for discharging and loading, and then leave the basin and the port at another high tide. Among the famous river ports of the world are London, Bristol, and Hull in England; Glasgow (glȧs′gō) in Scotland; Philadelphia, New Orleans, and Portland, Oregon, in the United States. Liverpool and Plymouth in England, Cherbourg, (shĕr′bo͞or′) and Marseilles (mar-sālz′) in France, Genoa (jĕn′ô-ȧ) in Italy, Yokohama (yō′kô-ha′mȧ) in Japan, and Los Angeles in the United States are famous for their breakwater systems.

Certain ports of the world, some of them very great ones, are known as "overside ports." In these a vessel transfers its cargo to a barge, lighter, or coastwise vessel that immediately carries the freight to other vessels lying in the harbor. Plainly, no great array of piers and warehouses is needed at any such port. London and Amsterdam are famous overside ports. At other ports, known as quay (kē) ports, the cargo of an incoming vessel is discharged to a pier. There it is stored, sorted, and reloaded to truck or railway, to be carried on to its final destination. At such a port one will find great "terminals" for receiving and storing goods. New York is America's greatest quay port, but Baltimore, New Orleans, San Francisco, and Portland, Oregon, are all important.

What Is a Port of Entry?

According to the business they are chiefly engaged in, ports are known as ports of entry or as transit ports. A port of entry



Traveling transporter cranes are part of the romance of the harbor. They move easily along the railroad tracks in order to reach the ends of the pile. This one in Wisconsin is loading a vessel with iron

depends upon markets. It is a great railway terminal and must have huge warehouse facilities. Most of our great American ports are of this kind as are also London and Liverpool, Hamburg and Bremen, Bordeaux, Marseilles, Yokohama and Buenos Aires (bwā'nos ī'rĭs) in Argentina. Since these ports are surrounded by vast, densely populated areas where there is a great deal of manufacturing and an enormous population demanding all sorts of articles, they naturally handle a wide variety of goods going both in and out. The natural and manufactured products of the surrounding region, which is known as the hinterland, are brought to the port by rivers and canals, by rail, and by truck. At the port they are put aboard craft that carry them to all parts of the world. In exchange, vessels carrying raw materials and manufactured goods from abroad discharge at such a port and their cargoes are then distributed throughout the hinterland. The great size of such ports as New York, Philadelphia, Baltimore and New Orleans is easy to understand when we remember that the greater part of the population of the United States is quickly and easily reached from those great gateways. Often a port of entry lies inland, as Albany and St Louis do.

America's great transit ports, Duluth, Buffalo and Galveston (găl'vĕs tun) are almost entirely given over to the handling of a single commodity. Duluth ships ore to the other Great Lake ports and some of it abroad through the Welland Canal which carries boats around Niagara Falls. Buffalo ships wheat; Galveston cotton and oil. Houston (hus'tŭn), Texas, really a canal port, since it lies fifty five miles from the Gulf of Mexico, with which it is connected by a channel cut through Galveston Bay, is chiefly given over to the shipment of oil. The transit ports of America serve hinterlands rich in natural products but rather sparsely settled. At these ports the cargoes are handled mechanically. Ore is hauled by train to the port of Duluth, and transferred to vessels by means of gravity. At Buffalo wheat and corn are mechanically hoisted into tall grain elevators whence they too pour into the holds of waiting vessels through the force of gravity alone.

The World's Greatest Port

Handling the wares that pass in and out of the port of New York presents vastly greater problems since here is loaded nearly every natural and manufactured commodity known to man. Management of the port involves the building, maintenance, and

supervision of piers and warehouses, tugboats, lighters, barges, and loading and unloading equipment of many kinds. There must be derricks and hoists for lifting barrels and boxes from the pier and setting them in the ship's hold. Sometimes, of course, it is necessary to lift a 500-ton locomotive and set it down in an ocean freighter. That is done by huge electric cranes, and done as carefully and effectively as you put the cap on your fountain pen. Besides machinery for handling cargoes, there must also be equipment for fueling vessels with either coal or oil, for victualing (vĭt″l-ĭng) vessels—that is, furnishing them with food supplies for a voyage—and for loading stores of fresh water and ice on ships not equipped to produce their own supplies.

Great staffs of workers have to be supplied and supervised at every large port. Hundreds of men examine and check every lot of freight to see that is is in good condition, that is is properly marked, and properly placed on shipboard. Thousands of other men—very skillful at their business—are busy day and night loading the vessels. Pilots who know the harbor channels must be on hand to bring ships up to the docks and to take other ships out to sea. There must be quarantine inspectors whose business it is to examine crew and cargo so that no incoming vessel may bring disease into the country. A corps of guards and watchmen patrols piers and warehouses to guard against theft of goods in shipment. Another corps of men supervises the handling of freight so as to guard against fires and explosions, since a vessel is as likely to carry dangerous chemicals, oils, and explosives in its cargo as it is to carry coal or cotton. And even coal and cotton are dangerous if improperly loaded.

Photo by U S Rubber Company

Large quantities of rubber latex reach the United States, where it is manufactured into the raw rubber so widely used to-day in making countless necessary articles, including the tires of the cars on which modern life depends. Unloading at New York is speeded up by bringing these railroad tank cars to the ship's side.

Strange as it may seem, the loading of a vessel is not only an art but also a science. A great many important things depend upon proper loading. First, unless the cargo is properly stored some of it may be badly damaged during the voyage. Since the owners of freight must be repaid for any damage done to the cargo, the steamship and insurance companies may lose a good deal of money unless the freight is properly placed. Second, a badly placed cargo may bring about damage to the ship, or even the loss of the vessel and its crew. Even in a gentle sea a ship rides unsteadily, in a storm the largest liner tosses about madly. Unless it is properly placed, the cargo shifts from side to side and the vessel is certain to develop a list—that is, to tilt to one side. When this happens the ship's machinery may be strained or broken and the vessel disabled. At the very least the ship is made less seaworthy and more difficult to manage. Plainly, the safety of the ship and all on board depends directly upon the storing of cargo. Third, if a ship is to make money for its owners, it must complete every voyage as quickly as it can and so make the greatest possible number of voyages in a year. The more quickly the vessel can discharge its cargo and take on another, the sooner it can set out upon a fresh voyage. And the speed with which it can do these things depends upon the skill

and judgment used in storing the cargo.

Oddly enough, the ship's crew neither loads nor unloads a vessel. The handling of a cargo is undertaken by a contractor known as a stevedore (stē'vĕ-dōr'). The men who actually do the work are called longshoremen. Hundreds of them are on hand whenever a vessel docks. They are hired for a shift of six hours at a time. Since the aim of the stevedore is to load the vessel as rapidly as possible, he is unwilling to employ any longshoreman for a longer time than his services are needed. Consequently any or all the longshoremen may be discharged at the end of six hours' work.

The proper placing of cargo in a vessel is known as "trimming." The ship must be so loaded that she rides the water on an even keel. Since a ship's cargo may include anything from a silk handkerchief to a steel rail, since some goods are shipped in barrels, others in bags, bales, and boxes, and still others loose, since some parcels are heavy, others fragile, some in crates, others uncrated, the proper storing of cargo is a complicated matter. Heavy parcels must be kept in place by "chocks" wedges or blocks of wood to prevent shifting when the ship rolls at sea. Mats, called "dunnage," must be placed between bales to avoid too much rubbing. Light and fragile parcels must be stored on top of larger, heavier ones. Shipments of strong-smelling goods, such as oils and spices, must be stored where they will not taint other items of the cargo, such as butter. Most important of all, the whole cargo must be so stored that any part of it may be reached immediately at the first port; for often only a part of the cargo is unloaded there and the space left in the hold may be filled again with goods of another kind altogether. When it is kept in mind that vessels on one steamship line between New York and Chile stop at forty-seven ports in the course of a single voyage, one can readily understand what skill is needed for properly placing a cargo.

Photo by Am. Museum of Nat. History

Through this busy port of Hongkong passes commerce between North and South China and between China and the outer world. But the ocean liners that carry it cannot go up the Pearl River beyond Whampoa, so Canton and many delta ports of the province of Kwantung must depend on quaint river boats called junks, and on these little covered craft called sampans.

Some commodities, such as coal, ore, and grain, are loaded in bulk. The entire hold of the vessel is filled with the cargo. But even a load of this kind must be properly trimmed, otherwise it will shift and settle, and the vessel will develop a list during the voyage. The hold must be well ventilated, so as to carry off explosive gases generated by grain and coal when they are stored in large quantities. Tankers vessels whose holds are filled with oil – must be ventilated and cooled as well, lest the heat of the sun cause gases to burst into flames.

When all such goods as have been mentioned and countless other sorts are unloaded, they must be cared for. All great ports have special docks set aside for the use of tankers, so that in case of fire other shipping will not be in danger. There must be refrigerated warehouses where cargoes of fruits and meats may be stored; these warehouses have rooms kept at different temperatures, so that each commodity may be suitably cared for. At every port there are yards for coal and for lumber, elevators for grain, and sheds for steel and mineral products. All such equipment is part of any great terminal.

To all the vast arrangements already described, still others must be added. There must be yards and shops for the repair of vessels. There is usually a dry dock where

a ship can be placed in a so-called "cradle" while the water around it is pumped away to allow the vessel's hull to be scraped and painted. There are fleets of tugboats for moving huge craft about in narrow places or shallow waters. Lighters and barges must be on hand for moving cargoes and freight about the harbor. Finally, an elaborate system of sirens, lights, buoys, and beacons must be kept in order, so that vessels may move about safely in the waters of the port.

How Big Is New York Harbor?

A modern harbor is indeed a city in itself. The waterfront of New York City, which is the world's greatest harbor, extends for 650 miles -a distance greater than the distance from New York City to Columbus, Ohio. The waters of the port are several hundred square miles in extent. And every two hours of the year an ocean-going vessel either enters this harbor or leaves it for some distant port.

Money for building and maintaining such gigantic enterprises as seaports comes from various sources. First, there are the fees. These are paid by shipowners for the right to dock, for the use of piers and other port equipment, and for the services of pilots and tugboats. Because these fees are very high, shipowners make every effort to get their vessels into port and out as quickly as possible. Other funds are contributed jointly by the national, state, and city governments. This money is raised by taxation, since everybody benefits from a port either directly or indirectly.

Because various agencies contribute to the support of a port, they are given joint control of the enterprise. In our own country the United States government has complete control of all navigable waters. Army engineers keep the harbor surveyed, attend to the widening and deepening of channels, and regulate the location and construction of piers, wharves, and warehouses. Quarantine inspection is also in the hands of the national government. The government of the state makes certain other regulations, as does also the government of the seaport city. The city often finances the building of piers and warehouses, some of which are rented for a term of years to shipowners who have sole use of them.

Who Manages a Port?

Since various agencies share the control of a port, affairs are usually simplified by turning over all details of management to a group of men known as a "port authority." This group includes financiers, engineers, architects, experienced shipowners and shipping managers, and other experts who are skilled in every phase of activity related to the conduct of the port. A place in the council of a port authority is of great importance, since the decisions of the members can determine the future not only of the port itself but also of the nation it serves. The well-being of mechanics and farmers and merchants who have never even seen the sea lies to a great degree in the hands of the nation's port authorities.

TRANSPORTATION

Reading Unit No. 14

INLAND WATERWAYS

Note: For basic information not found on this page, consult the general Index, Vol. 15.

For statistical and current facts, consult the Richards Year Book Index.

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Things to Think About

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Which of the important cities of the world are built on the banks of rivers?

What gave Berlin its great importance?

Why is Russia's means of communication poor?

How is China awakening to our modern world?

How great is the water-borne freight that passes Detroit?

Picture Hunt

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Summary Statement

Rivers and canals offer the cheapest of all means of transportation and in many countries are widely used for shipping bulky, slow-going goods. The United States has the most convenient system of waterways in the world. But though she uses it more than formerly, she is still far from making the most of it.

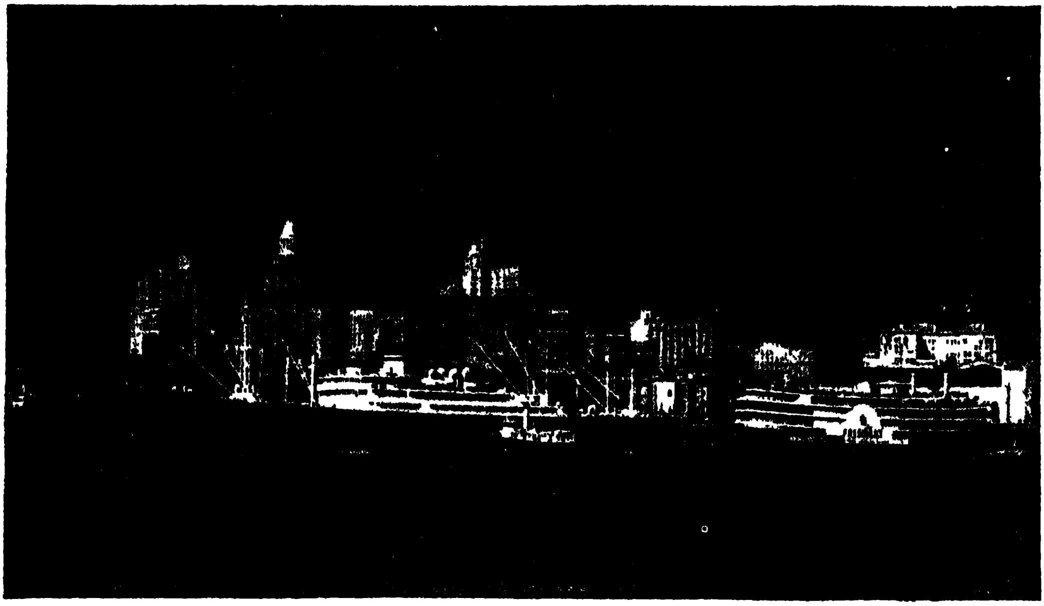

Photo by New Orleans Association of Commerce

This is the great river that carries cargoes into the heart of the United States. And this is New Orleans, largest city in the South and the nation's second busiest port. It is now an outlet for the whole Mississippi Valley. Though it stands at the nation's southern gateway it is not at the river's mouth, but is 107 miles upstream. The large ship at the left is unloading coffee from South America.

The GREAT CURRENTS *of* INLAND TRADE

Floating Down the Rivers, Rushing along the Rails, the Many Wares That Men Are Constantly Exchanging Are Carried Near and Far by a Great Network of Rivers, Canals, and Railroads

IF YOU should be given several billion dollars to build a great city, what kind of site would you choose? There would be a number of things to bear in mind. You would of course look about first of all for a prosperous, free nation—one where tyranny had not crushed the free expression of opinion and the search for truth, one where an enlightened people was in command of its own energies and not ground under the heel of a dictator or a ruling class. Only in such a nation could you hope for the stable government that is necessary for prosperity.

Next, of course, you would look for a country with rich soil or certain other physical resources, for great cities cannot thrive unless the people in and around them are able to earn a good living. Deserts do not support great centers of population. You would almost certainly plant your city in the Temperate Zone, for it seems to be there that men work best and live most vigorously. And you probably would choose the Northern Hemisphere in order to be in the heart of things, where there would be plenty of people to buy your city's wares. It costs money to ship goods a long distance.

Now if you had met all these requirements you would have a good start, but there would still be one thing you had not thought of, an advantage great cities seem to find it hard to do without. You would have to look about for a good river. If your city is to be a port, you will expect your river to furnish a water front for ships. If your city is built inland you will want your river to offer cheap transportation for your wares or perhaps cheap power for your factories and lights.

It may even furnish your water supply. It is hard for a first-class city to get along without a good serviceable river.

This was even truer before the day of modern invention. Ancient man depended on his rivers more than we depend on railroads. He loved them, and wove them into his life until he even came to worship them. To this day the Ganges (găn′jēz) is held sacred in India, and hundreds of thousands of believers make pilgrimages to bathe in its waters. In fact, to early men rivers often meant life itself. The Nile, the Tigris (tī′grĭs), and the Euphrates (u ...′ tēz) brought water to grow the crops of the greatest peoples of early history.

Then, as age followed age, streams began to carry more and more of the trade that grew as the nations grew. Though the ocean is the great highway of world commerce, the rivers were relied on for many centuries to take goods back and forth inside a nation's boundaries. And even to-day they give us our cheapest means of inland transportation. A boat needs no expensive roadbed to be kept in repair and patrolled day and night for the safety of passengers and goods.

PRINCIPAL FOREIGN RIVERS.

River.	Lg'th M's.	River.	Lg'th M's.
Albany	610	Neison	1,660
Amazon	3,900	Niger	2,600
Amu Darya	1,500	Nile	4,000
Amur	2,900	Ob	3,200
Arno	75	Oder	550
Athabaska	765	Orange	1,300
Backs	605	Orinoco	1,700
Brahmaputra	1,680	Ottawa	685
Bug (Dnieper)	500	Paraguay	1,500
Bug	450	Paraná′	2,450
Churchill	1,000	Peace	1,065
Congo	2,900	Pilcomayo	1,000
Danube	1,725	Po	420
Darling	1,160	Red (of No.)	545
Dnieper	1,400	Rhine	700
Dniester	800	Rhone	500
Don	1,100	Rio Negro	1,400
Drave	450	Riv. of Doubt	950
Dvina	400	Saguenay	405
Ebro	400	St John	390
Elbe	700	St. Lawrence	1,900
Euphrates	1,700	St. Maurice	325
Fraser	695	Salwin	1,750
Gambia	500	Sao Francisco	1,800
Ganges	1,540	Sask'tch'wan	1,205
Garonne	385	Seine	475
Hamilton	350	Shannon	250
Hwang-ho	2,700	Si	1,650
Indus	1,700	Sungari	1,130
Irawadi	1,250	Tagus	550
Jordan	200	Thames	215
Kootenay	400	Theiss	800
La Plata	2,300	Tiber	245
Lena	2,860	Tigris	1,150
Loire	650	Ural	1,400
Mackenzie	2,525	Vistula	630
Madeira .	2,000	Volga	2,300
Magdalena	950	Waikato	220
Maros	500	Weser	500
Marne	310	Yangtze	3,100
Mekong	2,500	Yenisei	2,800
Meuse	575	Zambezi	1,600
Murray	2,310		

Many of these great rivers of foreign lands are important water routes over which large quantities of commercial products are carried safely and cheaply.

The Famous Tiber

So if you will look at a map of the world you will find its great cities, for the most part, clinging to the banks of a river. Proud Rome, to be sure, had to content herself with the Tiber (tī′bẽr), a tiny stream and very muddy, but one of the largest in Italy. At its mouth was Ostia (ŏs′tyȧ), Rome's ancient busy port. To-day Rome carries on her trade by rail, and Genoa and Naples handle most of Italy's foreign commerce.

London was already standing on the placid Thames (tĕmz) when Roman legions first reached Britain, and to-day she is the world's second busiest port. Her magnificent docks see the loading or unloading of all the world's principal commodities—lumber, wool, metals, rubber, ivory, gasoline, silk, tobacco, meat, sugar, tea, foodstuffs of all sorts, rum, spices, wines and liquors, and all the multitude of manufactured articles that are made from these raw products to be shipped away again Before World War II a fifth of England's people lived in London, a quarter of her wealth was centered there, and a quarter of her industrial output—mostly in the lighter industries—came from that gigantic beehive.

Liverpool, too, on the Mersey River, is a world-famous port, for it is convenient to England's great manufacturing district. In particular, Liverpool handles raw and manufactured cotton. This busy section of England centers about a number of cities, and is commonly referred to as "the North," except where, around Birmingham and Stafford, it reaches down into "the Midlands." Manchester, that amazing industrial giant, is

Europe's most important river, the beautiful and romantic Rhine, has had a long history as an inland waterway. The Romans were probably the first to try to improve the channel and to make people pay for its upkeep. The Franks kept much the same system. Still later, the river fell into the hands of a number of greedy princelings who built castles on its rugged banks and collected taxes from all the ships that passed by. It is said that some of these petty princes put chains across the river just to make sure that no vessel would slip by without paying! Not until 1868 did the Rhine become a free river. To-day it is a fine highway.

one of these cities. Another is Birmingham, a center for the rubber, artificial silk, and motor industries, with busy iron manufacturies and factories for making glass and machinery. Stafford and the towns in its neighborhood have long been famous for pottery. Leeds is known for making clothing, machinery, woolens, and furniture, and for coal mining, fine printing, and the manufacture of leather. Canals connect it with Liverpool and with the Humber River. Then, too, in this same district is Sheffield, a name that the world connects with steel, which this busy town has long manufactured in the finest grades obtainable. And there is Bradford, England's great wool-manufacturing center, and the busy port of Hull on the Humber, with its great fishing fleet, its busy factories and shipyards, and its active shipping connections with the Scandinavian countries.

Famous Clydebank

Under this whole region in Northern England lie plentiful supplies of coal and iron, the real basis of the manufactures of the district. Newcastle-on-Tyne is famous for its shipment of coal and has a large shipbuilding industry, though in that it is far outdistanced by Glasgow, whose shipyards along the river Clyde build more vessels than any other yards in the world.

Mighty Manchester

Strangely enough, Manchester, though thirty-five miles inland, ranks next to London and Liverpool among British ports in the value of goods handled. She is at the center of a network of rivers and canals, and through the Manchester Ship Canal (1894) the immediate cause of her amazing growth she can send her wares to the sea and get the raw materials to carry on her mighty manufactures. Here is the world's largest center for cotton manufactures, which are nowadays carried on in the country around Manchester, with the warehouses and offices in the city. Here too is one of the world's largest centers for making all sorts of machinery, ranging from locomotives to plants for spinning and weaving. Besides all this, Manchester manufactures dyes, rubber, paper, ready-made clothing, and a host of other things.

On the continent of Europe, Paris has her place on a famous and useful stream. When she was only a little village she occupied an island in the Seine (sĕn), and all through the days when boats were small, seagoing vessels

came right to her door. To-day they must unload their cargoes at Havre (ȧ'vr'), the great port at the river's mouth. And yet the Seine now is made to work so hard that Paris is one of the busiest ports in France. She ranks along with Marseilles, largest of all the ports on the Mediterranean.

It is not only that the French capital sits at the crossroads of travel for all Western Europe, much as a spider might sit at the center of her web. Besides that, the gifted Parisians have made every year more and more beautiful and useful things out of the raw materials that come pouring in to them from every corner of the earth. Because Frenchmen are thrifty, they ship a good deal of their wine and timber and wheat, their fruit and oil and vegetables, their lumber and coal and iron and building products into Paris by boat. And by boat she can send out a part of the metal manufactures, the chemicals, the china and glass, leather, tobacco, food, and other manufactured articles which she has to sell.

PRINCIPAL RIVERS OF THE UNITED STATES

River	Miles	River	Miles
Alabama	315	Mohawk	148
Allegheny	325	Monongahela	128
Altamaha	137	Neuse	260
Androscoggin	171	New	255
Apalachicola	90	Niobrara	431
Arkansas	1,450	Ohio	981
Big Black (Miss.)	330	Osage	500
Black (Ark.)	280	Ouachita	605
Black Warrior	178	Pearl	490
Brazos	870	Pecos	735
Canadian	906	Peedee-Yadkin	435
Cape Fear	202	Penobscot	101
Cheyenne	290	Platte	310
Cimarron	600	Potomac	287
Clark Fork (Mont.)	505	Rappahannock	185
Colorado (Ariz.)	1,360	Red (La.)	1,018
Colorado (Tex.)	840	Red (Minn.)	545
Columbia	1,214	Republican	445
Connecticut	407	Rio Grande	1,800
Coosa	286	Roanoke	380
Cumberland	687	Rock (Ill.)	300
Delaware	296	Sabine	380
Des Moines	327	Sacramento	382
Dolores	230	St. Croix (Wis.)	164
Flint	205	St. Francis	425
Fox (Wis.)	175	St. Johns (Fla.)	276
French Broad	210	Salmon (Idaho)	420
Genesee	144	San Joaquin	350
Gila	630	Santee	143
Grand (Mich.)	260	Savannah	314
Green (Wyo.)	730	Schuylkill	131
Housatonic	148	Scioto	237
Hudson	306	Shenandoah-South Fork	155
Humboldt	290	Snake	1,038
Illinois	273	Susquehannah	444
James	340	Suwannee	190
Kanawha	97	Tallahatchie	301
Kansas	169	Tallapoosa	268
Kennebec	164	Tennessee	652
Kentucky	259	Tombigbee	409
Klamath	250	Trinity	360
Merrimack	110	Wabash	475
Miami	160	Washita	500
Milk	625	White (Ark.)	690
Minnesota	332	Willamette	190
Mississippi	2,470	Wisconsin	430
Mississippi-Missouri	3,988	Yazoo	188
Missouri	2,475	Yellowstone	671
Mobile	38	Yukon	1,800

Among these rivers are many to which our country will be able to turn when it is in need of more and cheaper transportation facilities.

The Charming Waterways of France

Paris can carry on this trade because the Seine has been woven into a network of some 7,500 miles of river and canal that extends over all of Northern France. A little boat starting from Paris can visit the Somme (sôm), the Scheldt (skĕlt), the Sambre (sôN'-br'), the Meuze (mûz), the Saone (sōn), the Loire (lwȧr), and even the distant Rhine. It can work its way to the teeming industrial centers of Northeastern France—such as Lille (lēl) and Roubaix (rōō'-bĕ'), with their great textile mills, or it can visit the coal and iron mines of Lorraine, or the wine-growing districts of Champagne (shăm-pān') and Burgundy (bûr'gŭn-dĭ).

More than that, our little boat with its train of barges can fare as far as the gallant Rhone (rōn), that famous river of Southern France which waters vineyards and olive groves and washes the walls of Lyons, with its great silk and dye and metal industries. France also has a canal from Arles (ȧrl), an ancient town on the Rhone, to Marseilles, which is now one of the world's chief centers for importing and processing vegetable oils, such as olive, peanut, cottonseed, cocoanut, and palm oil. Much of these raw materials the city makes into soap. Such a canal will bring to Marseilles by boat the wine, tiles, bricks, olive oil, and other exports which now have to come at least part of the way by rail. And it will also open up the

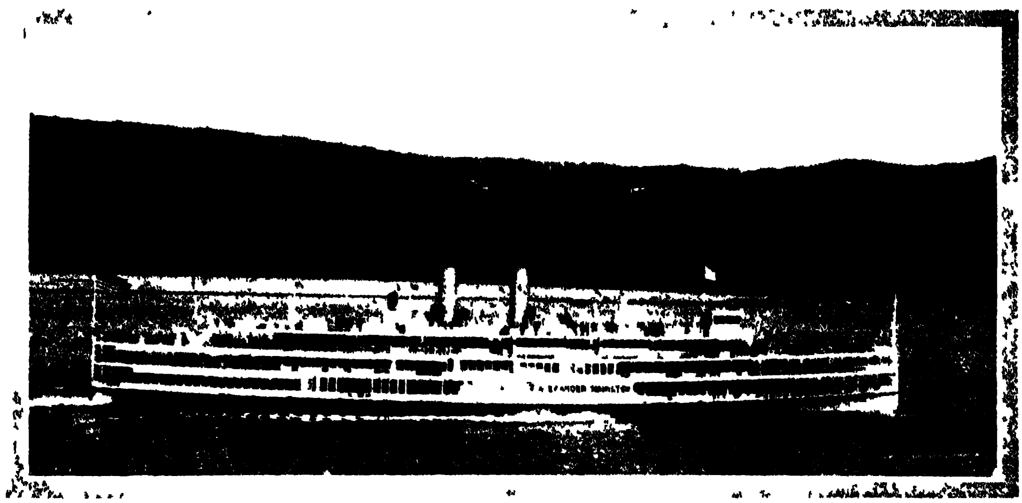

Photo by Hudson River Day Line

The Hudson River, through whose calm waters this passenger boat is making its way, is not a river in the true sense of the word. It is really a drowned river valley. The ocean has entered the mouth of the Hudson, and ocean tides are felt as far north as Albany, 150 miles above the harbor If the land were to rise only a little, the Hudson would become a small, rather insignificant stream, and New York would be without its magnificent harbor and its convenient waterway. It would cease to be our greatest city

Rhone to a still heavier traffic, for at present the river's mouth is blocked by silt. The Rhone Valley is rich in both wine and olive oil. In fact France in general is a wine-drinking country, and leads the world in wine production. Bordeaux (bôr'dō'), a large port on the western coast, is a famous wine center.

Europe's Manufacturing District

France is not the only European country that knows how to use its waterways. No continent in the world is so well off for water transport. A great deal of money has been spent in improving rivers and digging canals, but it has paid handsomely in reducing freight rates. If you were to draw lines connecting Belfast in Ireland, Warsaw in Poland, Vienna in Austria, and Marseilles in France, you would have roughly inclosed Europe's pre-war manufacturing region, where the shipper had better and cheaper means of transportation than can be found anywhere else in the world. For this he had to thank the fine waterways on which his heavy, slow-going freight was moved. Although Europe is larger than the United States and has four times as many people, she had some 20,000 miles less of railroad. But she made up for this by putting to constant use her more than 90,000 miles of inland waterway. Only fast traffic went by rail.

The greatest of Europe's inland water routes is the storied Rhine (rīn), a magnificent stream dear to every German heart Large sums have been spent to make it navigable for the 550 miles from the sea to the thriving city of Basel (bä'z l) in Switzerland. At the great port of Rotterdam, on the river near its mouth, and at Amsterdam and Antwerp, two other famous ports not far away, goods are reloaded from ocean vessels to river boats, to be carried into the heart of the greatest industrial region in Europe.

Upstream comes grain from Russia, the United States, Roumania, and the Argentine —and a good many other kinds of goods that Germany must import. Downstream go coal and iron from the famous Ruhr (ro͞or) Valley and, formerly, iron and steel manufactures, for here were centered Germany's heavy industries The famous Krupp ironworks were at Essen, in the Ruhr Valley.

Storied City of the Rhine

Busy cities follow on one another's heels along the Rhine, all of them served by railroads. There is Basel, where goods are transferred to the St. Gotthard (gŏth'ärd) railway to go down into Italy by way of the railroad's famous nine-mile tunnel. Some of this freight is loaded on ocean-going vessels at Genoa. Next comes Strasbourg (stras'-

bōōr′), in France, where vineyards begin to spread their orderly rows over the fields and terraces along the river's banks—for the Rhineland holds one of the world's famous wine-growing regions. Mainz (mīnts), in Germany, is the last Rhine port that large boats coming upstream are able to reach. It is the chief center for the shipment of wine, and transfers other goods as well.

At Mainz the large Main (mīn) River joins the Rhine. It has come down past the great city of Frankfurt, a thriving commercial and industrial center; and above that it has helped water the hopyards of Bavaria (bà-vā′rĭ-à), a section of Germany famous for its beer. The Germans are a beer-drinking people, and make more of it than any country in the world except the United States. In Bavaria is the city of Munich (mū′nĭk), once Germany's fourth city in size and the center of many fine crafts. Here too was the famous old town of Nuremberg (nū′rĕm-bûrg), which outdistanced Munich in commercial importance. In America we know it for its toys and fine wood and ivory carvings. It is the great hop market of Europe.

AREAS OF GREAT RIVER BASINS.

The areas in square miles of the greater river basins, according to the best estimates, are as follows:

Amazon (So. Amer.), 2,772,000 square miles; Congo (Africa), 1,425,000; Nile (Africa), 1,293,000; Mississippi (U. S.), 1,290,000; La Plata (So. Amer.), 1,198,000; Ob (Siberia) 1,125,000; Yenisei (Siberia), 980,000; Lena (Siberia), 895,500; Yangtze (China), 689,000.

Mackenzie (Canada), 682,000; Volga (U. S. S. R.), 592,000; Ganges and Brahmaputra (Asia), 588,000; Niger (Africa), 584,000; St. Lawrence (Canada-U. S.), 565,200; Zambezi (So. Africa), 513,500; Orinoco (So. Amer.), 430,000; Amur (Asia), 403,000; Orange (So. Africa), 400,000.

Hoang-ho (China), 387,000; Indus (Asia), 372,000; Winnipeg-Nelson (Canada), 370,800; Yukon (Canada-Alaska), 330,000; Danube (Europe), 320,300; Columbia (Canada-U. S.), 298,000; Murray (Australia), 270,000; Rio Grande (Mexico-U. S.), 232,300; São Francisco (Brazil), 212,900; Dnieper (Europe), 202,400.

Most of the world's rain water is caught by the great river basins listed above. The pattern of one of these basins is much the pattern of a giant tree whose branches the river's tributaries stretch out into the hills. The trunk of the tree is the great river after which the basin is named.

What Did Cologne Make?

Going on down the Rhine from Mainz we come to Coblenz (kō′blĕnts), another Rhine port important in the wine trade. Below it Cologne (kô-lōn′), which had many factories, especially in the "heavy industries," was the third city in Germany in size. All these towns, and Dusseldorf (düs′ĕl-dôrf) as well, were busy commercial and industrial centers before World War II, and owed a large measure of their prosperity to the cheap transportation they got along their great river.

But Germany has plenty of other rivers to carry her heavy freight. For instance, there is the Weser (vā′zĕr), wearing as its chief ornament the great city of Bremen (brā′mĕn), which ranked second among German ports and was a busy center for shipbuilding and manufacturing of various kinds.

East of the Weser lies the Elbe (ĕl′bē), a stream that is navigable well into Czechoslovakia (chĕk′ô-slô-vä′kĭ-à), and furnishes that country with its quickest water outlet to the sea. On its way to the North Sea the Elbe passes Dresden (drĕz′dĕn), a famous center of art and culture, with a busy commerce by way of the Elbe and various railroads. Dresden manufactures a large variety of articles, and is especially famous for her china and musical instruments. The Elbe here finds its way through Saxony, the most productive agricultural region in all Germany, and a little farther on it passes Magdeburg (mäg′dē-bōōrK), in the heart of Germany's best sugar-beet region.

The Famous Leipzig Fairs

By way of smaller streams and canals a boat on the Elbe can reach Leipzig (līp′sĭk), Germany's fifth city in size, a famous musical and literary center and the seat of what is said to be the largest book industry in the world. Here a number of great fairs are held every year, to be visited by merchants from Europe and Asia, who come to buy or sell furs, leather, hides, and wool. Leipzig was a center for a large number of industries of all sorts.

At the mouth of the Elbe lies Hamburg, before the war the greatest port in Europe and Germany's second city in size. She

Photo by Wheeling W. Va. C. of C.

This is a scene on the Ohio River, one of the important waterways of the United States. The flat-bottomed steamboat in the picture was characteristic of both the Ohio and the Mississippi rivers. You may read an exciting account of the old steamboat days in Mark Twain's "Life on the Mississippi."

exported more German goods than any other city; machinery, electrical goods, sugar—of which Germany extracts a great deal from beets—iron and steel, dairy products, fertilizer, cement, china, glass, paper, and beer. A large number of these things she made herself, and she built a great many ships besides. Into her ample docks came ships loaded with coffee, tea, sugar, spices, rice, grain, tobacco, and many other raw materials and provisions. For Germany is a crowded country that had to turn to manufacturing to support her people, for that reason she imported food and raw materials to make up and sell abroad.

What Is the Port for Berlin?

East of the Elbe the Oder (ō'dẽr) leads from the Baltic Sea into the heart of Eastern Germany, Poland, and Czechoslovakia. Near its mouth is Stettin (shtĕ-tēn'), another of Germany's great commercial and industrial cities, and a large center for shipbuilding. It is the principal port for Berlin.

For Germany's great capital, once the chief commercial and industrial center on the Continent and the third largest city in Europe, lies well back from the sea and is not even on a large river. But she is at the center of a great network of railroads and of canals. The Spree (shprā), on which she is built, is connected by canal with both the Elbe and the Oder, and through the Oder with other rivers farther east, so that boats can travel from Berlin (bûr-lĭn') to Hamburg, and in the other direction to the great centers of Eastern Germany. Berlin's great importance was largely due to this network of eastern waterways, in which the rivers, running in general north and south, are joined by canals running east and west. It would be hard to list all of Berlin's many manufactures. They lay in every field, and were turned out in vast amounts. She was Germany's largest city.

East of the Oder the next great river to cross the plain of Northern Europe and enter the Baltic Sea is the Vistula (vĭs'chū-lȧ), a Polish stream that rises in Czechoslovakia and carries freight from Warsaw down to the Gulf of Danzig (dan'tsĭK). One of its tributaries is joined by canal with a tributary of the Oder.

Rivers of Eastern Europe

East of the Vistula the Niemen (nē'mĕn) brings down goods from Russia and Poland through Lithuania (lĭth'ū-ā'nĭ-ȧ) and East Prussia, where it is known as the Memel (mā'mĕl). Its cargoes are such as its neighborhood produces—timber, grain, agricultural products, and fish.

Still farther east lies the Dvina (dvē-nä'), a Russian river that crosses Latvia on its way to the Gulf of Riga (rē'gȧ). Canals join it to the Volga and the Dnieper (nē'pẽr), two great rivers of Russia. On its way it passes by the Latvian city of Dvinsk (dvēnsk). Though it is interrupted by a good many rapids it and its many branches serve the people of Western Russia by carrying rafts of timber. These drift along to the song of the gypsies who tend the rafts and live in little grass huts that they build on top of the logs. The city of Riga lies near the river's mouth, a thriving center of commerce and manufacture. Here fish, sugar, foodstuffs, tobacco, coal, fertilizer, clothing, and machinery are gathered from across the seas, in exchange for the flax and timber that Latvia exports.

The Blue Danube

Now all these busy streams pouring into the North and the Baltic seas furnish excellent highways for the farmers and manufacturers of Northern Europe, but are of little help to those farther south. Must the great wheat fields of Hungary send out their produce by rail only? Not at all. Through the heart of Central Europe and down to the Black Sea flows one of earth's greatest rivers. It is the mighty Danube (dăn'ūb), which for century after century has been the great highway of Southeastern Europe, the center of many wars and the subject of countless poems.

When Germany Controlled the Danube

Before her downfall in World War II Germany planned to build a serviceable canal that should link her northern waterways with this great international highway. There is, it is true, a small canal between the Danube and the Main. It is called the Ludwig Canal, and it passes through the city of Nuremberg. But it is not a real highway of commerce. So pretty much all the countries along the Danube Austria, Hungary, Czechoslovakia, Roumania, Yugoslavia (yōō'gō-slä'vĭ-ȧ), and Bulgaria—face south toward the Black Sea and use the Danube for a highway to trade among themselves and to take down timber and grain for shipment across the ocean. Their boats bring back petroleum and a variety of manufactured articles. Ocean vessels can come up the river to the grain-shipping port of Braila (brä-ē'lȧ), in Roumania. There, and at Galatz (gä'läts), goods are loaded to river boats and barges.

The Danube is navigable up to Regensburg, in Germany, and boasts a number of capitals along its course—gay Vienna (vĭ-ĕn'ȧ), now dimmed and poverty-stricken but long a center for the arts and for the manufacture of beautiful and expensive goods like fine leathers and silks and jewelry; Budapest (bōō'dȧ-pĕst'), the chief outlet for grain and live-stock products from the plains of Hungary; and Belgrade (bĕl'grād'), which handles most of Yugoslavia's foreign trade, largely carried on with neighboring manufacturing countries. Russia now controls the Danube a powerful link in the chains she has bound around Eastern Europe.

Scandinavia's Beautiful Streams

Norway and Sweden, Spain, Italy, and Greece are handicapped in the matter of navigable rivers. The two Scandinavian countries use their beautiful but tempestuous streams to float down logs from their fine forests or to generate electric power. Both have canal systems, which are linked by a lake on the border. The Swedish ports of Gothenburg (gŏt'ĕn-bûrg) and Stockholm are joined by 360 miles of waterway, most of it following various little rivers.

Spain, Italy, and Greece are mountainous lands without much rainfall, and their rivers are mostly short and unfit for shipping. Barcelona (bär'sē-lō'nȧ), the principal Spanish port and center for the leading manufacturing and commercial district in Spain, has to rely on railroads to carry her goods inland. And so does Valencia (vä-lĕn'shĭ-ȧ), the second port of Spain, a shipping point for grain and fruit raised on the rich plain that lies around her. Seville (sĕv'ĭl), it is true, is on the Guadalquivir (gwä'däl-kwĭv'ẽr), which can be ascended as far as the city by the boats that take away wine, fruit, ores, olives, olive oil, and wool.

Italy has a fairly large river in the Po, but one so choked with silt that it is of little use

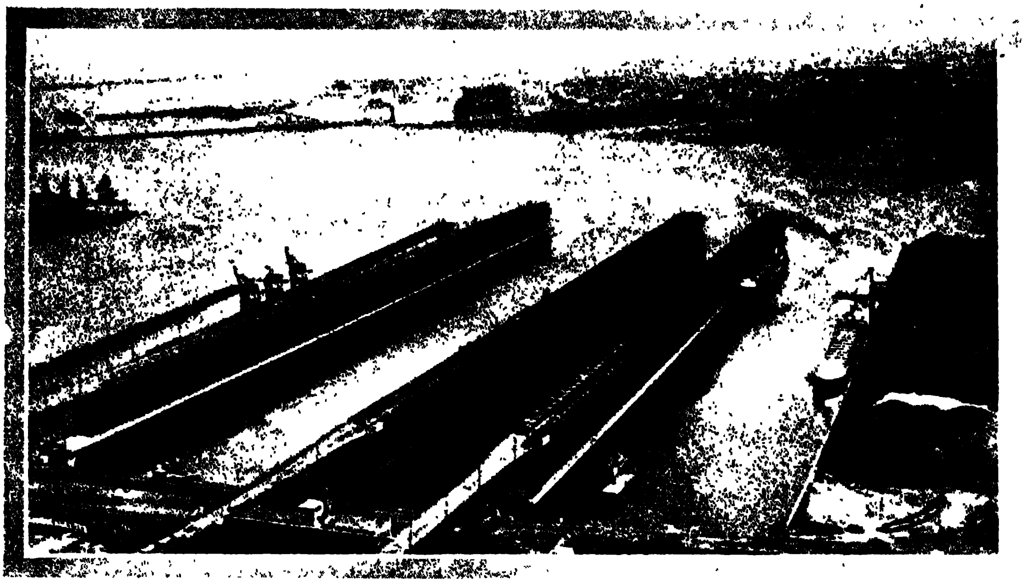

Photo by Duluth C. of C.

These great docks are in the harbor at Duluth, Lake Superior's most important port. Iron ore from the huge open pits of the Mesabi Range is brought here by train and then loaded into the ore boats that are shown in the picture. They will carry the ore cheaply to ports on the lower Great Lakes. Then it will go to the great smelting centers—Pittsburgh, Pennsylvania; Gary, Indiana; and a number of cities in Ohio.

for shipping. It serves the Italian people well, in spite of that, for it and its tributaries, tumbling down from the glaciers in the Alps, bring loads of rich soil and generate much of the power to run Italian factories. These are centered in the valley of the Po and its tributaries. Milan (mĭl'ăn), Italy's wealthiest city and her chief industrial and commercial center, lies here on the "Lombard plain." She manufactures machinery and iron products, textiles of all sorts, furniture, clothing, velvets, leather, and countless other articles. Turin (tū'rĭn), not far away, is the center for the Italian motor industry, and makes a great variety of other things besides, ranging all the way from soap and candles to airplanes.

What Is Italy's Greatest Port?

Venice (vĕn'ĭs), at the other end of the Lombard plain, was once a great port, but her harbor has been pretty well filled in with silt. To-day she makes beautiful glass, fine textiles and lace. Trieste (trē-ĕst'), once Italy's eastern port, is now under the United Nations. Italy's greatest port is Genoa. Here goods come by rail from Italy and Switzerland and Southern Germany. She ships hemp and flax that are grown on the fertile Lombard plain, olive oil and wine, cheese and fruit and flour, steel and paper and marble, and velvets and gloves. Into her docks from abroad come grain and cotton and coal and machinery for the teeming populations inland.

A Gigantic Network of Rivers

So far we have spoken of small countries where crowding makes it necessary to use the greatest thrift in handling all the resources that Nature provides. In the late 1920's, Russia, a country of tremendous size, launched a long-term plan to develop her waterways on a really big scale. In spite of the fact that this country ranks next to the United States in railroad mileage now, vast stretches of Russia's dense forests and endless grassy steppes (stĕp'), or treeless plains, then had no means of transportation. It was not uncommon for people in one section to starve while food went to waste in another section. Building enough railroads to do the job of transporting their goods, especially in wartime, would be a long and costly project, and transportation facilities were essential to the big overall plans by which

the new communist government was attempting to modernize the country. Besides, Russia turned naturally to water transport. She had always used her rivers for trade, and her territorial growth had followed the rivers of Eastern Europe and Northern Asia.

Mother Volga

According to the plan, the Volga (vŏl'gå) River, that great stream which meanders from the Gulf of Finland down to the Caspian (kăs'pĭ-ăn) Sea, was to be the heart of a great waterway system. Every important river in European Russia, as well as a number in Asia, was to be woven into the fabric. And six oceans and seas were also to be made to serve the nation. The project included dredging rivers to rid them of their accumulation of silt, narrowing channels, and building dams. By controlling the flow, there would be water for irrigation and electric power.

The plan also included borrowing water from the Don River, which flows near the Volga at the point where the city of Stalingrad (stä'lĕn-grat') stands, to increase the Volga's supply. Otherwise, so much water might be drained away from the Caspian Sea making an already salt lake saltier that the very valuable fish in it would die. Of course making the Don and one of its tributaries, the Donetz (dŏ-nyĕts'), a water highway was also part of the overall scheme. Russia's busiest coal mines lie in the Donetz basin. By building canals and other improvements to put the mighty Dnieper (nē'pĕr) to work, coal could be transported more cheaply. Then, too, oil boats from Baku (ba-kōō'), a port on the Caspian Sea, could sail up the Volga, down the Don, and over to the Dnieper and on to the great grain, wool, and cattle port of Odessa (ō-dĕs'ä).

War Interrupted the Plan

Exactly how much of Russia's whole plan for a unified waterway system is now a reality it is impossible to say. World War II interrupted this type of work there considerably, as it did in all countries. After the war Russia made it practically impossible for people outside the "Iron Curtain" to get accurate information about what went on. Important improvements were made before and in the early years of the war, however. In the 1930's the usefulness of the Dnieper was greatly increased by the building of a dam and locks around the rapids at Dnepropetroosk (d'nyĕ'prō-pyĕ-trôfsk'), one of the greatest hydroelectric stations in the world. Ocean-going vessels could sail up the Dnieper a thousand miles. The great dam was partially destroyed during the war to keep it from falling into the hands of the Germans, and had to be rebuilt. But there were also canals linking the Dnieper to the Baltic. These were at the head waters of the Pripet (prĕp'ĕt), the Dnieper's western tributary. The King's Canal in Poland joins the Pripet to the Bug (bōōg) River, a tributary of the Vistula which washes the walls of Warsaw and the important city of Danzig on the Baltic. The Vistula, in turn, connects with the rivers of Germany and completes the water route between that country and the great ports on the Baltic and Caspian seas.

Linking Sea to Sea

But this is not the only route by which boats can travel inland to the northern seas. A long series of rivers and canals was completed to link the headwaters of the Volga to the Baltic. And the Baltic-White Sea waterway joins the White Sea to the great port of Leningrad (lĕn'ĭn-grăd) on the Baltic. Leningrad manufactures many sorts of heavy machinery engines, steamships, and factory equipment—as well as textiles, clothing, and other articles. It is a big advantage for her to get coal, iron, and other raw materials by boat from Southern Russia in this inexpensive way. Moscow (mŏs'kō), the Russian capital and an important trade center, can also get materials for her many manufactures by way of the Volga. She is connected with it by an eighty-mile canal—in many respects the greatest canal in the world.

A Trade Route through the Arctic

The Baltic-White Sea route cuts nearly 2,200 miles from the regular water route from Leningrad formerly called Petrograd (pĕt'rō-grăd)—to Archangel (ärk'ān'jĕl), on the White Sea. Archangel has a large fishing industry and manufactures fish products.

Budapest, shown above, and Vienna are the two most important cities on the "beautiful blue Danube." It is a sad fact that the waters of this magnificent stream are as often yellow as blue, for the current is strong and the river often carries a heavy load of silt from the countries it washes farther upstream.

Her principal export is timber from the dense northern forests. Russia now keeps this important harbor open the year round by using ice breakers, and its trade has greatly increased.

Lack of ice-free ports has long handicapped Russia. Of her 40,600 miles of coastline ¾ is largely ice-bound. Only Batum (bä-tōōm′) on the Black Sea, Petropavlovsk (pyĕ′trô-päv′lôfsk) on the Bering Sea, and Murmansk (mōōr-mänsk′) on the Barents (bä′rĕnts) Sea are ice-free the year round. The Arctic route was very valuable to Russia during World War II. Many war supplies went to her from the United States through this northern route. It is a connecting link of tremendous value between European Russia and the Russian Far East.

Odessa to Vladivostok

When goods had to be shipped from Odessa to Vladivostok (vlȧ′dĭ-vŏs-tôk′) through the Suez Canal, they had to travel over 13,000 miles. By way of the Panama Canal, it is over 14,000 miles. Now, by way of river and canal to Murmansk through the Arctic Sea, the distance is less than 7,000 miles. From the United States, whether one leaves from Seattle or New York, the best route to Archangel is through the Arctic.

The advantages of the new water transportation facilities to Russia—of her harbors and inland routes—are immeasurable and they have been built against great odds. It is to be hoped that the day will soon come when we shall not only know more about their extent, but that people everywhere will share in their benefits as trade and ideas flow freely into and out of this vast country.

Trade Routes in an Ancient Land

Nature has given Russia's neighbors on the South—those ancient, romantic lands that have linked the East and West since the dawn of history—very little in the way of navigable inland waters. There is now a railroad almost all the way across northern Iran (ē-rän′). The Trans-Iranian, which is the main line, follows the ancient trade route from Teheran (tĕ-h′rän′) down to Baghdad. Teheran, once famous largely as a rug market, is now remembered also as one of the meeting places of the Allied leaders in World War II, where war strategy was discussed and postwar plans made. From Baghdad trains may go north through the storied lands of Mesopotamia (mĕs′ō-pô-tā′mĭ-ȧ), now known as Iraq (ē-räk′). Transportation is needed here, too, for moving the wool, dates, minerals, and especially the oil at Mosul (mō′sōōl′).

But the lands in this part of the world have too few railroads to carry their interesting wares. Their magnificent oil wells are located, luckily, on the Persian Gulf, where it si very easy to reach the sea by only a few miles of railroad and pipeline. The Tigris and

Euphrates (ū-frā'tēz) rivers, rich in ancient history, can carry just a little local traffic until they unite to form the Shatt al Arab (shät ȧl ȧ-räb') at Basra (bŭs'rȧ). The passage from this busy port down to the Persian Gulf is practically the only inland water transportation to be found in these hot arid lands.

This is the land of the caravan where, over trade routes centuries old, some of the most precious wares in the world have traveled between the East and West. And camel and donkey caravans are no novelty in many sections, even today.

Before and during World War II there was great interest in building modern transportation here. What had already been built some 1,500 miles of railroads and 9,000 miles of highway was put to good use when it became so important to get war supplies to Russia. The Allies actually took over the operation of the main railroads and surfaced many miles of highways for motor trucks in the most strategic sections.

Providing transportation in the so-called Middle East as well as in Asia is a hard job. The Trans-Iranian railroad was very difficult to build because of the dry, mountainous nature of the country and because almost all the materials had to be imported. It was also very costly. There is still hope, however, that Iran may extend her railroads to connect with the line from India at Zahidan (zä'hē-dän') and perhaps in the north from Mashhad (mȧsh-hȧd') to join with the Russian line just over the frontier. Nearly every town of any size now has an airport. Though very few of them have surfaced runways, or can accommodate any except the smallest planes, facilities for air transportation might be improved instead of building railroads.

Lands of Turmoil and Change

We cannot go by inland water route, but if we leave behind the sands and caravans and travel farther and farther east, we find ourselves in a part of the world torn with turmoil and change. The future is hard to predict. In the countries of India, China, and Southern Asia we hear prophecies of growing industrialization, general improvements, and increased trade, but we must bide our time to see what happens, knowing that the India of tomorrow will be vastly different from the India of today.

In its newly found freedom India bustles with trade. Inland, goods are carried mainly by the railroads which were built under British supervision when India was under British rule. The reason for this is not that India has no rivers. One thinks at once of the sacred Ganges (găn'jēz) and the Jumna, or the Indus and the Brahmaputra (bra'mȧ-pōō'trȧ). But these rivers are by nature as turbulent as the monsoon climate of India. The canals, dams, and locks which have been built so far are used mainly for irrigation.

The Picturesque Chinese Junk

When Japan invaded China in 1937, the Chinese government had to set aside the plans it had made for improving the all-important inland waterways. China has always made great use of her rivers. The two largest ones, running east and west, are joined in many places by a system of canals which run north and south. These were not built in the modern way, with dams and power stations for making electricity. But they have served to carry the quaint little junks that crowd the Chinese rivers—strange-looking craft that hoist a sail to catch a favoring wind, and otherwise make their tedious way by poling and towing. Millions of Chinese people know no other homes than the junks which, generation after generation, have earned them a living.

Northern China is handicapped without navigable rivers. The great Hwangho (hwäng'hō'), or Yellow River, is shallow, loaded with silt, and very changeable. It is called "China's Sorrow" because its awful floods often drown the precious rice lands and shift the channel again and again. The chief city in its broad valley is Tientsin (tĭn'tsĭn'), the port for the old capital city of Peiping. Traffic on the Hwangho is mostly local.

The Great River of China

In its character the Hwangho is entirely unlike the great Yangtze (yäng'tsĕ'), a steady and dependable stream that, in spite of rapids thousands of miles from its mouth, is the

Photo by N Y C Times.

Here is a view of the Erie Canal, a waterway designed before the days of the railroad to provide cheap transportation between the states around the Great Lakes and those along the Atlantic seaboard.

great artery of trade for the busiest part of China. Its vast fertile delta reaches to Nanking (năn′kĭng′), 235 miles inland and a seat of the Communist government. It supports the densest population in the world an average of 7,000 people to a square mile. At the river's mouth sprawls Shanghai (shăng′hī′), the most important port in the Far East and the center of China's manufacturing industry. It is easy to see why Shanghai should have grown. The Yangtze Valley is the home of nearly half the Chinese, and in one way or another the river handles half of China's commerce. Along its lower course crops flourish all year. Here China's finest silk is grown, and here is her best cotton, rice, and tea district.

The Port of Shanghai

Before World War II paralyzed China's foreign trade, Shanghai was an all-important port for goods coming in from other countries and for products going out to them. With her own coal fields undeveloped, China relied on Japan for coal. India provided much staple cotton for making cloth. England sent a variety of manufactured products, chief among them, cotton goods. The petroleum products, machinery, wheat, and tobacco which entered Shanghai came largely from the United States, which is China's best customer. In times of peace China sent the United States quantities of silk, soybeans, and tung oil, and probably she will do so again when normal trade returns.

China's trade since World War II has tended to be more and more restricted to the Soviet Union, which has supported the Chinese Communist government, and large quantities of goods have been carried by airplane. But good-sized river boats still go up the Yangtze to Nanking, for some time a manufacturing center, particularly of silk, paper, and pottery. Besides selling these products, Nanking has a thriving business in skins, beans, meat, and dairy products. But she has to buy her cotton cloth, metals, sugar, and kerosene. It begins to be clear why the river boats are kept busy

In the dry season ocean vessels cannot get up to Hankow, the great trading city of Central China and the point where the Canton Peiping railroad ferries cross the river. Hankow distributes goods throughout the whole country, exports tea, and is a center for China's young iron and steel industry. By the time the river reaches Chungking, China's World War II capital, it is useful largely for local traffic.

The Beautiful Grand Canal

Ever since the sixth century before Christ the Grand Canal has carried goods from the Yangtze Basin northward. It extends altogether about a thousand miles, from Hangchow to Tungchow. However, the changes in the course of the Hwangho have often made it impossible to use certain parts. It was a means of saving many Chinese craft from the Japanese during the war, and, though it

has fallen out of repair, it is still an important carrier of freight and passengers.

China's Southern Door

Canton is the trading center for Southern China. At its warehouses the produce brought down the West River can be transferred to ocean vessels which reach Canton by way of the Pearl River, or it can be shipped to Hongkong on the Canton-Kowloon railroad. Canton is the birthplace of the 1911 revolution led by Sun Yat-sen (sōōn' yät'sĕn'), which drove out the Tsing Dowager Empress and gave China a democratic government. A little more than 30 miles southeast by railroad lies the British-owned island of Hong Kong. Until recently it and Singapore, another British possession, were among the busiest ports in the Far East. When fighting began between the armies of the Nationalist government and the Communists, trade all over China was slowed down or carried on only with the greatest difficulty. Of course all the long-discussed plans for peaceful industrialization and improved transportation took second place. The Chinese people had to give their time to the job of earning a living, much as they had always done. There were growing signs of a Machine Age in some areas in the use of airplanes, for example. But human muscles still carried much of the goods and provided the power used for other purposes.

Japan and Australia

The island empire of Japan has always relied on ships to carry her goods from island to island. Partly because of her use of inexpensive transportation she became the greatest trading nation in the Far East. Of course her trade was destroyed with her defeat in World War II, but it is reviving under the control of the American Occupation Forces.

The desert wastes of the island continent of Australia do not give rise to rivers. Most of the trade of the coastal settlements is carried on in coastal vessels or on railroads that the government has helped to build.

Waterfalls and Jungles

There is no lack of rivers in Africa. Magnificent streams like the Congo are capable of bringing to the coast all the interesting products of the jungle. But almost all the rivers tumble in waterfalls over the edge of the plateau that reaches almost to the sea. The few railroad lines cling to the coast, and caravans, ox trains, and men carry the inland goods. The long-talked-of Cape to Cairo railroad will probably never be finished, now that airplanes promise more efficient transportation.

Shipping on most of South America's great rivers the Orinoco (ō'rĭ-nō'kō), the Amazon, and La Plata (la plä'tå) - is limited because of the tropical jungles through which they flow. Here again the airplane is taking over the load.

Waterways in the United States

No country has a finer inland waterway system than the United States. Immediately we think of the broad, sleepy Mississippi, flowing through the very heart of the country, of the Great Lakes, the blue Hudson, and dozens of other streams.

But a mention of the well-known rivers and lakes does not begin to tell the whole story of waterways in America. With the improvements that have been made on Nature's gifts, the United States' inland waterways now have reached a total of almost 30,000 miles, which in one postwar year carried some 668,000,000 tons of goods.

The Intracoastal Waterways

The Atlantic Coastal System forms an almost continuous water route 4,000 miles in length from Boston to Florida. It connects with many inland streams and also with the sea. The Gulf Coastal System, similar but somewhat shorter, reaches west from Florida across the United States to Brownsville, Texas. With the exception of the Mississippi and the Tombigbee (tŏm-bĭg'bē), few of the rivers which drain into it are navigable very far up stream. But the main line provides a cheap freight route and a pleasant passageway to sailors of small boats.

Because of their falls and rapids, the rivers of the Pacific Coast carry very few boats. The Columbia, the San Joaquin (săn wä-kēn'), and the Sacramento are partially navigable—but only for very short distances.

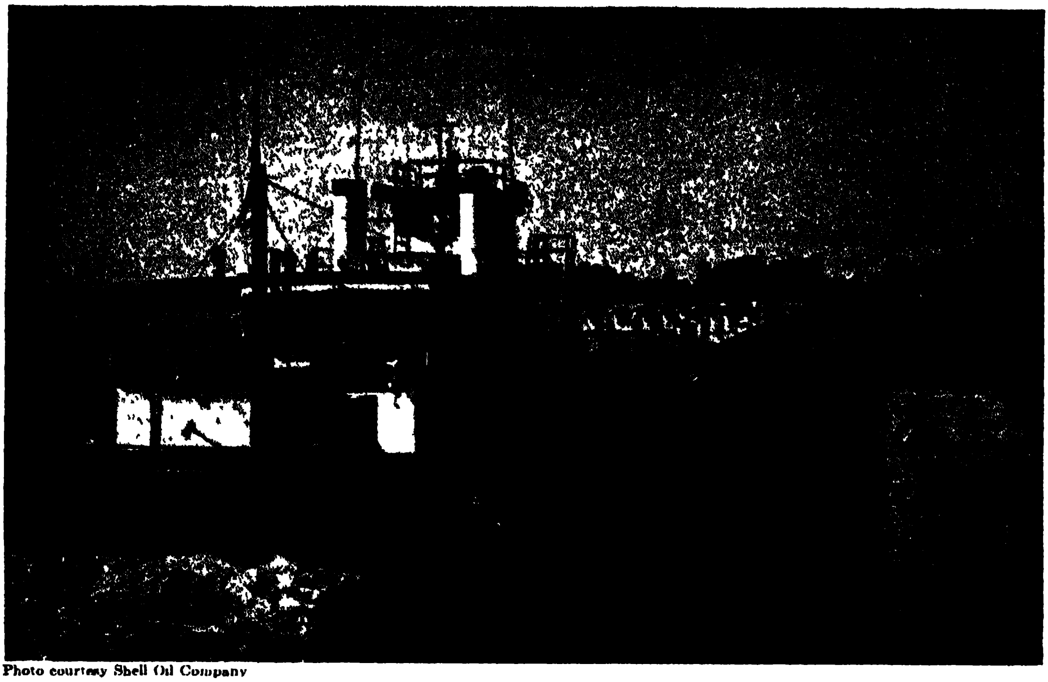

Photo courtesy Shell Oil Company

These 400,000-gallon barges on the Mississippi are being loaded with gasoline, kerosene, or fuel oil. The powerful tug that is bringing them up for loading will tow them north to St. Paul or east to New York or New England. Such barge trains and there are thousands of them give us our cheapest means of transportation.

The two greatest systems of all in the United States are the Mississippi and the Great Lakes. The Mississippi and its tributaries have been improved so that they form a chain of 8,000 miles of navigable waters. Seagoing vessels can go up the Mississippi as far as Baton Rouge (băt'ŭn rōōzh'), and barges can ply the river to Minneapolis. The Ohio is navigable some distance above Pittsburgh, and big boats can sail the Tennessee as far as Knoxville. The Illinois River and the Illinois Waterway connect the Mississippi with Lake Michigan. Vessels of medium size can use the Missouri as far as Sioux (sōō') City, Iowa.

The channels connecting the Great Lakes have been improved to take care of increasing traffic through them. Besides their connection with the Mississippi by way of the Illinois Waterway, they provide a passage to the Atlantic through the St. Lawrence, and to New York by way of the New York State Barge Canal and the Hudson. Along these waterways massive freight can move without reloading from the Middle West to the coast. Iron ore from Minnesota and limestone from Canada are sent over them to join the coal from Pennsylvania and be made into steel the product that has been called the backbone of America's industrial greatness. In time the steel is turned into machinery, refrigerators, automobiles, and hundreds of other articles which find their way back along the same water routes which carried the raw materials to the manufacturer.

Waterways Are Uncle Sam's Business

The United States government has spent more than a billion and a quarter dollars improving the national waterways. Most of the work is carried on by Army engineers. The Tennessee Valley Authority is in charge of that great project. Money spent on improving waterways is usually money saved. Not only is water transportation cheaper, but improved waterways also control floods and often make water available for power and irrigation. In addition to competing with the railroads to bring down the cost of transportation, waterways are more and more needed to help railroads and trucks move the gigantic quantities of goods the nation

turns out. This was made very clear during World War II when the nation's total resources were enlisted for victory. Water transportation increased tremendously then, and for the first time shipbuilding was carried on in inland cities, which were both less crowded and safer than cities along the coast. Inland waterways made it possible to move the ships or sections of ships down to the sea.

More Improvements Are Needed

Much has been done, but the United States has not yet made the best use of her lakes and rivers. Every year floods take their toll of lives and property. One of the projects which has been suggested is a waterway from the head of the Ohio to Lake Erie. This would shorten the present Mississippi River–Great Lakes route from the Gulf of Mexico to the East. Some experts say that if there had been such a route in World War II, much of the terrible destruction of lives and materials by submarines that preyed on coastal shipping could have been prevented. As a national defense measure, the project is still considered sound.

For many years the Government has debated another project that would increase the use of the St. Lawrence River as a seaway and add to the nation's supply of electric power. If this project were put into effect, it would be done jointly with Canada, a friendly neighbor with whom the United States has always shared the use of the Great Lakes. Those who urge the St. Lawrence Seaway project point out that in case of a national emergency it would be an excellent route for transporting iron ore from the new mines of Labrador. World War II cut down the United States' supply of ore seriously. If another war should come both the United States and Canada would probably need to mine the Labrador deposits.

The World's Busiest Waterway

Of course, the United States and Canada already make good use of the St. Lawrence River, which, combined with the Great Lakes, is the busiest waterway in the world. America buys more from Canada than any other country—and sells more to her, too. A large share of the exchange of goods is made by way of this route. The Detroit River, a part of the system, carries more goods up and down its waters than make up the foreign trade of New York, Liverpool, and London combined. The canal at Sault Ste. Marie (sōō'sânt mà-rē'), Ontario, has carried a total of well over 100 million tons a year since World War II, when it broke all previous records. In bulk, iron ore and coal make up the biggest part of the cargoes, but in value, wheat from the Middle West and the Prairie Provinces ranks first.

Quebec, Three Rivers, and Montreal can compete with the proudest ports anywhere. Quebec is seated where the St. Charles joins the St. Lawrence and is a terminal for the varied products of the St. Charles Valley. Three Rivers, serving a similar purpose for the valley of the St. Maurice, gets its name from the three channels into which it divides as it meets the St. Lawrence. Montreal was formerly little more than a towpath, but since the Lachine Canal was built, placing the city on a water highway, it has grown into the world's largest inland port.

Six Canal Systems

Canada has six canal systems "feeding" and extending transportation on the St. Lawrence "main." Besides the one that provides passage from Fort William and Port Arthur through the Sault Ste. Marie, there are waterways between Montreal and Ottawa and south to the international boundary near Lake Champlain. Then there is a water passage from Ottawa to Kingston; one from Trenton to Lake Huron; and another from the Atlantic to Bras d'Or (brä' dôr') Lakes in Cape Breton. These six systems have added over 1,800 miles to Canada's waterways. Of course, there are many smaller canals and deepened channels for local shipping.

Where Winter Locks the Rivers

The Canadian government has seen to it that shipping shall be possible in less favored parts of the Dominion, too. Ocean, lake, and river craft can dock at Chicoutimi (shē'kōō'tē'mē'), a port on the Saguenay (săg'ē-nā') River that serves a region noted for its aluminum, paper, pulp, and agricultural pro-

Photo courtesy Royal Canadian Air Force

Here in Fort William, Ontario, the Kaministikwia River carries huge loads of grain to the very doors of the grain elevators, where it will be stored until needed. From this point it can be sped to market in freight cars.

ducts. Like many other Canadian ports, its shipping period is limited because of ice. The season is from the middle of April to December 1st. But the port of Churchill on the river of the same name has an even shorter season. This port was discovered in 1619 but not developed until the 1930's. Now it is the point of departure for grain from the Prairie Provinces bound for Europe by way of Hudson Bay—but only from August to mid-October. Grain, lumber, and minerals are also carried down the Nelson River nearby, from which they go on out through Port Nelson and Hudson Bay.

As in the United States, Canada's system of waterways is a "companion and aid" to her railways. Both the Canadian National and the Canadian Pacific cross the continent with feeder lines running north and south. The completion of the Canadian Pacific in 1885 and of the Panama Canal in 1914 is largely responsible for the growth of Vancouver (văn-kōō'vēr) in British Columbia. Lying inland and safe from heavy winds and ice this port has one of the finest natural harbors in the world. But inland shipping in the region back of it is impossible because the country is mountainous. Without the railroads to feed it Vancouver could not have become a great outlet for such products as vegetable oils, grain, lumber, and fish.

When We Must Figure Costs

It is the shipping around and on the Great Lakes, however, that provides the life blood for Canada's economic prosperity. Much of the busy life of both farm and factory in Canada and the United States would be stifled if boats should cease to ply the waters of these inland seas. When cost counts rather than speed, these waterways are unequaled for the carrying of all sorts of bulky products from mine, farm, and mill. And the steady stream of tonnage that can be moved by slow-going barge and boat makes up for lack of speed whenever goods are not of the sort to spoil during a long journey. Every year increases the importance of our waterways.

TRANSPORTATION

Reading Unit No. 15

HOW WE HAVE MADE ROADS OF WATER

Note: For basic information not found on this page, consult the general Index, Vol. 15.

For statistical and current facts consult the Richards Year Book Index.

Interesting Facts Explained

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Why canals were dug in ancient days, 10 269-70

Why Lesseps failed in his attempt to dig the Panama Canal, 10 270

How a ship climbs a hill, 10 272

The Panama Canal, 10 273

The famous Suez and Kiel Canals, 10-274

Things to Think About

Why was the Suez Canal easier to dig than the Panama?

Why are canals dug?

Why was the first attempt to dig the Panama Canal unsuccessful?

How do locks lift heavy ships over a hill?

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Leisure-time Activities

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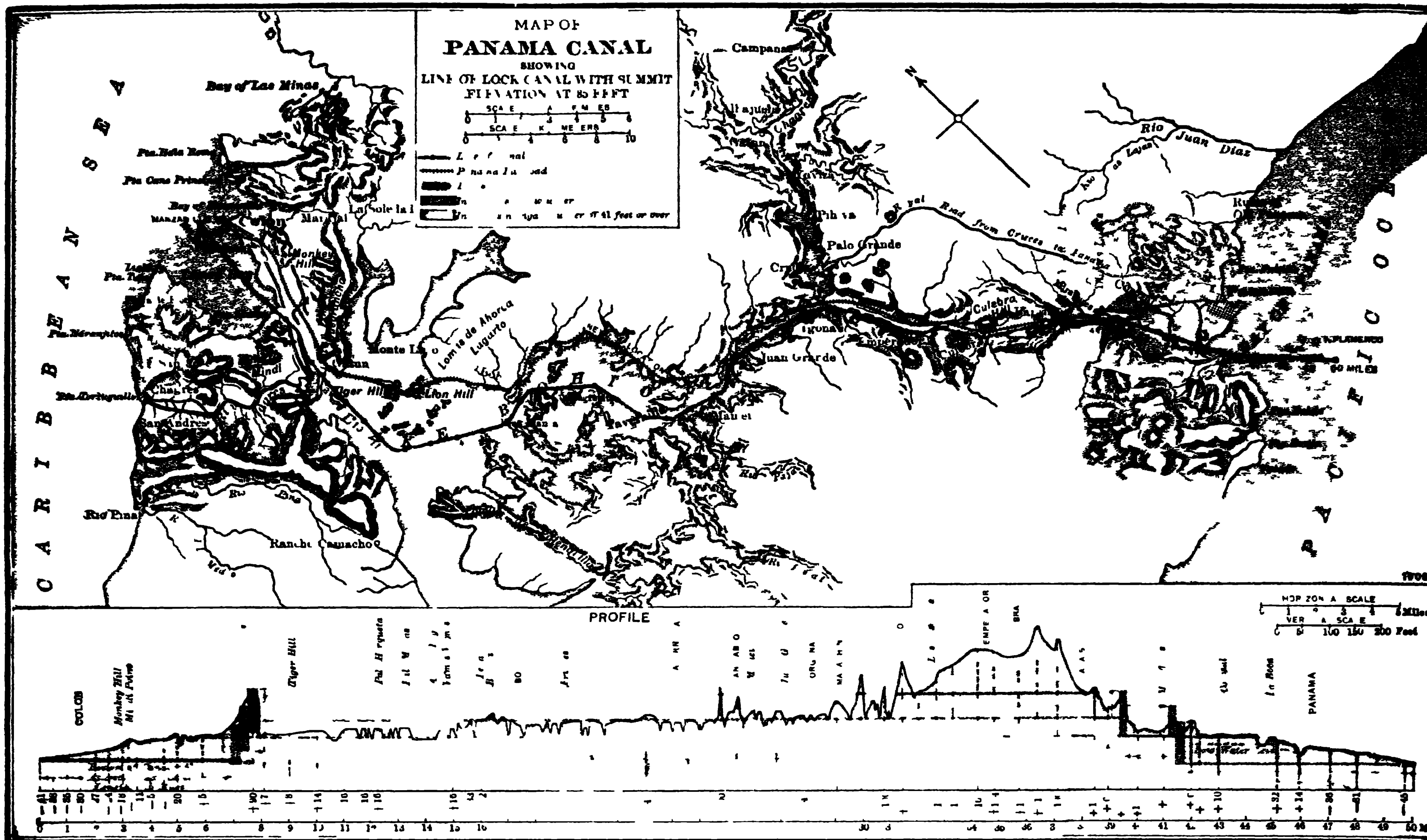
PROJECT NO 2. Make a clay relief map of the Panama Canal, 10 273

Summary Statement

We dig canals to save great distances, to link cities together, to let ships come up to inland cities, and sometimes we dig them to drain off water from marshes or to bring water to deserts where there is too little moisture



FOATES ENGR CO.

The historic battleship *Missouri*, on which the Japanese signed the document of surrender in World War II, is here shown passing through the Panama Canal. She has just left the Miraflores locks behind her.

HOW WE HAVE MADE ROADS *of* WATER

The Little Canals That Wind Their Way from Town to Town, and the Big Ones That May Save Us a Trip All the Way around a Continent

THERE is a place where you can walk all the way across America in one day. It is at Panama; and if ever the creator of this curious world smiled at his own work, it surely must have been when he tied North and South America together with a little thread of land only thirty miles across.

Only a few years ago a boat on the Atlantic side of Panama had to go nearly eight thousand miles around South America to reach a point on the Pacific side just thirty miles away. Of course the captain always said, "Why not cut a canal?" And many another man put the same question. In fact, it had been asked within less than twenty years after Columbus died. But it was not answered until nearly four hundred years later, when the Panama Canal was opened in 1914 as the greatest water road that man has ever built.

Of course men had to build water roads for a long while before they learned how to cut a Panama Canal. They needed waterways for many things. Sometimes they could save a great distance, as at Panama and Suez, where they now go through a short canal instead of sailing all the way around a continent. Sometimes they had no other good way from one city to another; or if there was no big river, they either had to haul everything on wagons or they had to build a waterway of their own. Sometimes their city was fifty or so miles distant from the sea; and since they could not move the city to the coast, they cut a canal to let the ships come right up to the city. And sometimes they dug canals merely to carry

off the water from a marsh where there was too much of it, or to bring the water to a desert where there was too little.

So they began to dig canals in ancient days. Three thousand years ago there was a short canal in Egypt from the Nile to the Red Sea, and in the Roman empire there were many of them. The Romans were always good at waterworks. The Chinese had a great canal eight hundred years ago. By the time of Columbus, Europe was pretty well cut up with waterways of man's own making. But they had all been made in level land, where it was fairly easy; for not until about the time of Columbus did we learn how to take a ship over a hill or a small mountain. How we do that can be shown in the story of the great canal through Panama.

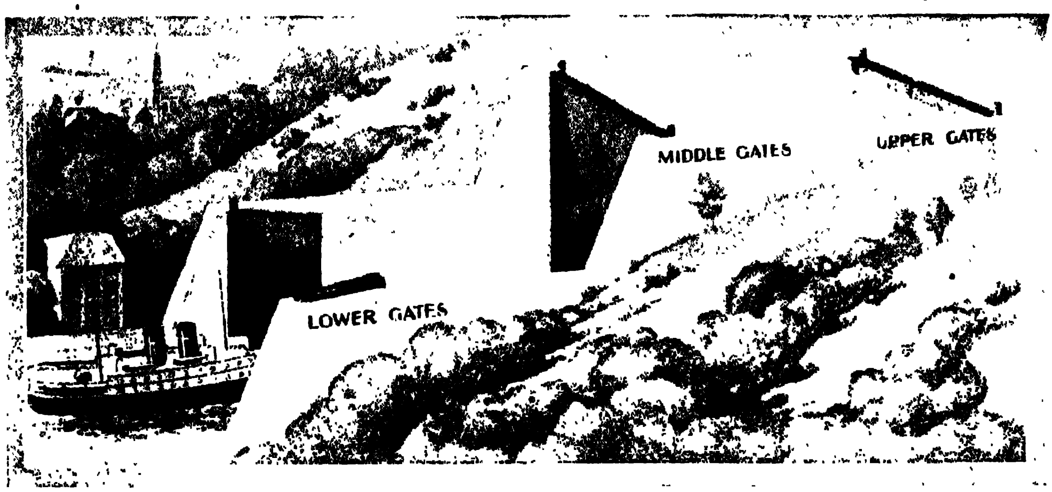
Photos by Swedish State Railways.

In Sweden is the Göta (yû'tȧ) Canal, fifty-four miles long in all, with fifty-eight locks. At Trollhättan it surmounts some famous falls by an amazing staircase of locks. Here are pictures of the canal taken from the air and from the path beside it.

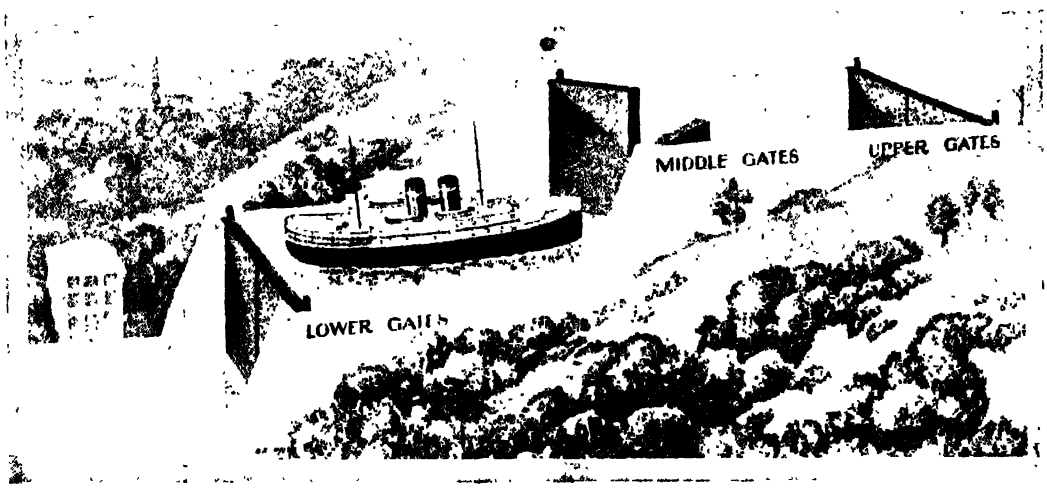
In 1881 the famous French engineer, Ferdinand de Lesseps, began to dig the Panama Canal. He had already dug the one at Suez, and was ready for a greater task. But though he knew all about canals, he knew very little about mosquitoes—or about the terrible diseases like malaria and yellow fever that they used to give to strangers in Panama; and his workmen grew sick and died in great numbers. Also his company had too little money, and was too dishonest in wasting what it had; so that by 1889 the company was bankrupt. In the end they sold out to the United States.

In 1903, after some delay, the United States started to cut the canal. In the first place they sent down a small army of doctors to make war on the mosquitoes, and the doctors did so well that Panama was soon one of the healthiest places in the world. Then the engineers and laborers could come. The work was put in charge of the American Army, and under the command of General George W. Goethals (gō'thălz) it was carried through in about ten years. Some of the hard things he had to do can be seen if we now take an imaginary trip through his canal.

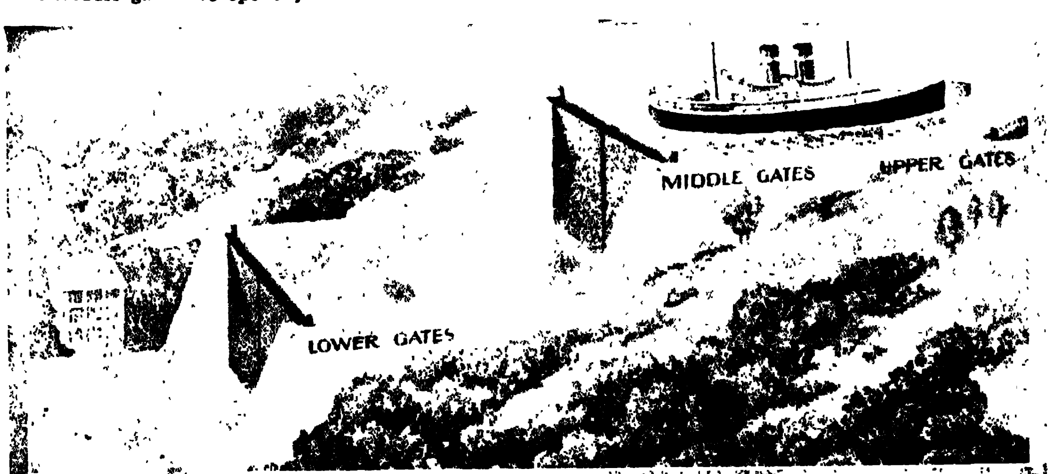
Let us suppose we are on the biggest battleship. We sail in from the Atlantic, past the city of Colon, and in three or four miles we reach the Gatun (gä-tōōn') Locks. Here the land rises, and we shall have to lift our battleship about eighty feet.



How a ship climbs uphill! First it sails into the lowest lock, and the gates are closed behind it.



The middle gates are opened, and the water from above raises the boat, which then enters the next lock.



When the middle gates are closed behind it and the upper gates opened, the boat rises to the topmost level.

This the locks will do. We sail slowly into the first lock, or rather we are pulled into it with ropes by six locomotives on the banks—for no ship can take the chance of sailing into the lock under her own steam. She might crash. The lock is an immense concrete basin, 1,000 feet long, 110 feet wide, and 81 feet deep. The biggest boat in the world can be at home there. It took over 2,000,000 cubic yards of concrete to put up the Gatun Locks.

Photo by Panama Canal

This is the place where a mountain was moved to make way for the Panama Canal. It is the famous Gaillard Cut. In a single year 2,500 tons of dynamite were exploded there to chisel through the crest of the continental divide, which at once retaliated by pouring down millions of tons of rock upon all the operations Dynamite and the steam shovel and perseverance finally conquered. But it took a great deal of the last!

How a Ship Climbs a Hill

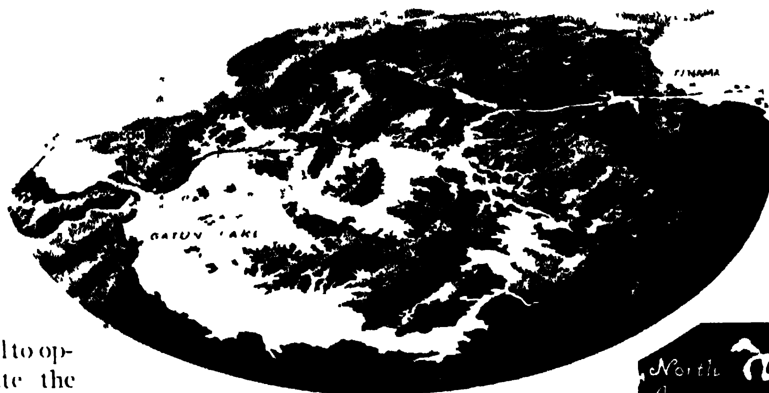
Once we are inside, the gates are closed behind us and the water begins to pour in under us. That may sound easy, and so it is, indeed, in Panama; but one of those vast steel gates which the electric power opens and shuts so easily weighs about 500 tons—for it is 7 feet thick, 65 feet wide, and as high as a six-story house, or sometimes higher. And the water has to pour in very rapidly if it is going to fill up our lock; so there are 105 great sluices to let it in. As it comes in, our great ship rises with it And when the lock is full we are on a level with the water in another lock right in front of us. A great gate opens before us, and we are pulled into the second lock.

The same thing happens again. The water pours in to lift us to the level of the third lock. And this raises us once more till we can sail ahead into Gatun Lake. Our battleship has risen about eighty feet, and it has taken about an hour to get up. While we were going up in our locks, we may have seen boats going down in the three locks right beside us. For all the locks are double, and a boat may be going down in one set while another is going up in the other set. To let a boat down, the water is simply allowed to run out of the lock. Then the boat goes on into the next lower one.

A Great Lake Made by Man

But now we are in Gatun Lake. There was no lake here in the beginning. The engineers had to make it by putting a great

dam across a river running through the land. The great Gatun Dam is about a mile and a half long and about half a mile thick at the bottom. It forms a lake that not only lets us steam on for another twenty miles, but furnishes power enough to make all the electricity needed to run the canal works, to light up the whole district, and to operate the telephones and telegraphs.



When we get through the lake we come to another marvel of the engineers. It is the famous Gaillard Cut through the hilly backbone of the isthmus. This is simply an immense ditch cut through the hills—about eight miles long, between three and six hundred feet wide at the bottom, and as much as three thousand feet across at the top. Out of the cuts in the canal came enough dirt and rock to build a mountain two miles long, a mile wide, and a thousand feet in height. But the mere size was not the only problem in the Gaillard. The earth above kept pressing and sliding down into the ditch; and even when the engineers thought they were through they had to begin all over again as the landslides came down and filled up the channel.

Beyond this cut is the Pedro Miguel (pē′drō mē-gĕl′) Lock, through which we now begin to go down. It puts us out into a little lake a mile long, through which we reach the two locks of Miraflores (mē′rä-flō′rās). These let us down fifty-five feet to sea level again. And now we steam on for five or six miles to the city of Panama. We are in the Pacific. It has taken about eight hours to get through.

The Panama Canal was such a huge thing that some men really thought it could never be completed. A few more figures may give a better idea of its size. The earth dug out of it weighed 360,000,000 tons. It took 307 locomotives and 4,572 cars to carry this off. To blast away the rock required 77,000,000 pounds of explosives, and at one time over 50,000 pounds were set off at a single blast. The whole work cost $373,000,000.

If you were a bird on the wing, this is the way the Panama Canal would look to you. From the map in the square you may see how much it shortens the journey by water from New York to San Francisco.

Photo by American Museum of Natural History

The canal is open on equal terms to vessels of trade or war belonging to all countries. Thousands of ships of all kinds pass through it every year, and they pay us many millions of dollars in tolls. Lumber from Oregon and wheat from Western Canada go through to Europe. Motor cars from New York or Detroit take this way to Chile and Peru. Fruit comes through from California to the East, and wool from Australia to New Eng-

land—with many other things from many places. And thousands of passengers saii through to save time and to see the sights.

Just as the Panama Canal saves time in the Western World, so does the Suez in the East. In fact, it is the gate between the East and the West; and the phrase "East of Suez" has come to mean anywhere in the Orient.

Built by the same Frenchman who started the work at Panama, the Suez (sōō-ĕz') Canal was finished in 1869, after ten years of digging. It is ninety-eight miles long, or two and a half times longer than the Panama. But it is all at sea level, and mostly runs through sand and clay. So there was no great trouble in constructing it except to keep right on through the long task. There were a few low hills to cut through and four shallow lakes to dredge; but for thirty miles the Suez goes straight across the desert. It cost $83,000,000. Though built by the French, it is now mainly under British control.

Of course there is an immense trade through it—for it saves five thousand miles of travel around Africa. Since 1885 it has been greatly improved, and it is now wide enough for ships to pass one another at any point. It takes about fifteen hours to get through.

The next most famous canal is the Kiel (kēl). It runs through Germany from the North Sea to the Baltic. In part it was made for commerce, but in the main for war—in order that the battleships of Germany might get through rapidly and safely from one coast to another. The locks at each end are even larger than those at Panama, and they have to lift the boats some forty-six feet. The canal is eighty-five miles long, and saves about two hundred miles of travel.

There are many other canals for large ships. There is the Manchester Ship Canal, which brings the vessels from the ocean right up to the great city of Manchester, thirty-five miles from the coast in England. There is the Sault Sainte Marie (sōō' sânt mā'rĭ) Canal in northern Michigan, connecting Lake Superior with Lake Huron and bringing the boats laden with iron ore down from Duluth. And there is the Canadian canal that goes around Niagara Falls; it is the Welland Canal, from Lake Erie to Lake Ontario. Many a shipload of wheat goes through it on the way to Europe.

All these waterways are "ship canals," that is, they are big enough for ocean ships to use. But there are thousands of smaller canals, in many lands, on which lesser boats and barges float about the country. They are placid little waterways, and sometimes very pretty; and they are mainly used for shipping bulky articles that do not need to hurry. For travel is pretty slow on them. Usually the barge is pulled by a horse that walks along the towpath.

There are more of these canals in Europe than in America, for Europe had been digging them for a much longer time before the railway came. In France and in Holland there is a real network of them, and there are a great many in England and in other countries. In America we had not been cutting them for very long before the railway arrived and almost entirely took their place. For of course the railway has stolen a great deal of the trade that these thriving canals used to do. The most famous barge canal in America was the Erie, from Buffalo to the Hudson River. It was once a great carrier of passengers and freight. In recent years it has been improved and made into the New York State Barge Canal. It now carries an increasing tonnage of bulky goods, but is of even greater value for its help in flood control.

TRANSPORTATION

Reading Unit
No. 16

EVERYWHERE ON WHEELS OF AIR

Note: For basic information not found on this page, consult the general Index, Vol. 15.

For statistical and current facts, consult the Richards Year Book Index.

Interesting Facts Explained

What the first automobiles were like, 10-277

Why automobile inventors were discouraged in England, 10-278

Daimler's internal-combustion engine, 10-278

The early gasoline motor cars, 10-278

When there were only four gasoline cars in the United States, 10-278

How Henry Ford "put the mob in automobile," 10-279

Things to Think About

How do we feed gasoline to the cylinders of our automobiles?

How do the brakes make driving safe?

How does the spark from the spark plug work?

How is the automobile engine cooled?

How does the engine of an automobile turn the two drive wheels?

Picture Hunt

What did the early automobiles look like? 10-280

Why does the driver press down the clutch to shift gears or to stop his car? 10-289

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When will our petroleum wells be exhausted? 1-152

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How are automobile tires made? 9-260, 270

Practical Applications

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What part does the automobile play in commerce? 10-281

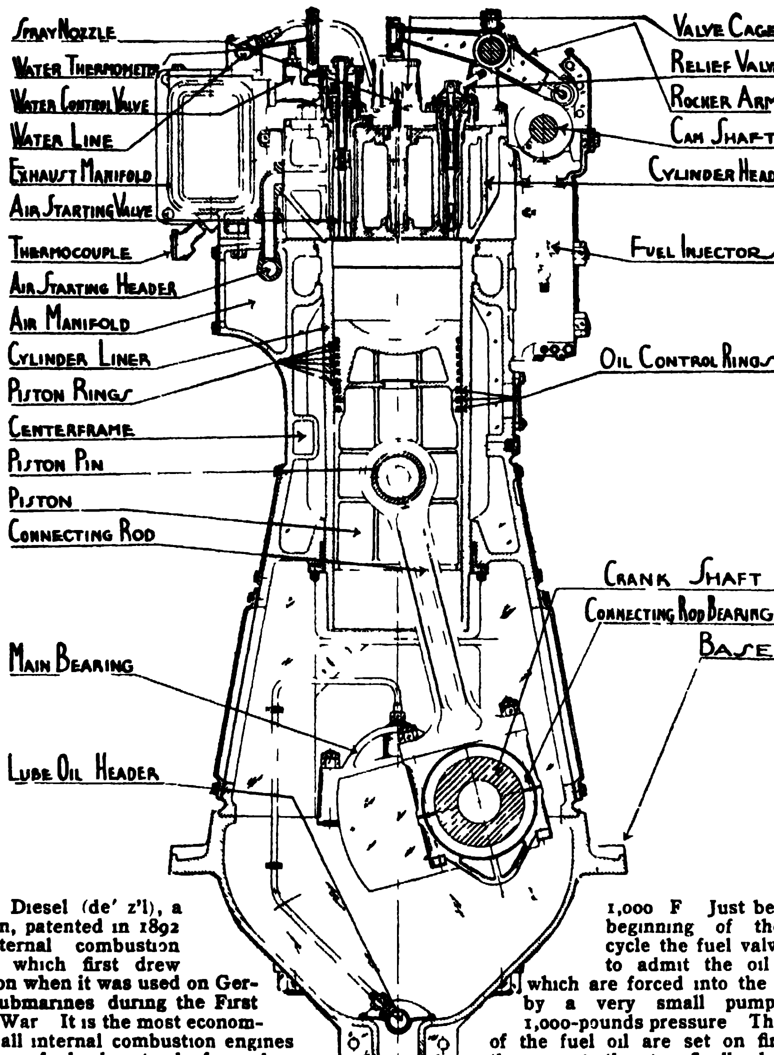
Leisure-time Activities

PROJECT NO. 1: Learn why the automobile engine purrs, 10-287

PROJECT NO. 2: Examine the engine of an automobile, and learn how it works, 10-290-91

Summary Statement

The automobile has brought freedom to both the farmer and the city dweller, and has laced the whole land together with strong bands of good roads that should help to destroy sectionalism.



Rudolf Diesel (de' z'l), a German, patented in 1892 an internal combustion engine which first drew attention when it was used on German submarines during the First World War. It is the most economical of all internal combustion engines – it burns fuel oil instead of gasoline and gets more power from its fuel. It takes up less space than a steam plant, and for this reason is valuable for submarines and for large boats where room for freight is wanted. To-day Diesels are used on trucks, buses, large ocean liners, and in sewage plants, water-power plants, oil pipe-line stations, and many other places. They are built into locomotives and are being perfected for airplanes. The accompanying diagram shows how a four-cycle Diesel engine works, and how it differs from gasoline engines in compressing the mixture further.

During the first cycle pure air is drawn into the cylinder. Next, the piston, on its return stroke, compresses this air to a pressure of 400 or 500 pounds per square inch. This raises the temperature of the air to about 1,000 F. Just before the beginning of the third cycle the fuel valve opens to admit the oil vapors, which are forced into the cylinder by a very small pump under 1,000-pounds pressure. The vapors of the fuel oil are set on fire when they meet the terrifically hot compressed air in the cylinder, and this explosion furnishes the power stroke of the engine. The waste gases are removed during the fourth cycle. No ignition system is necessary.

Special means of cooling such engines are provided. This is done by forcing a current of water through the water jacket which surrounds the cylinders. In marine and stationary engines, where the water supply is plentiful, cold water is driven by a pump into one opening of the water jacket and out through another.

A much more compact Diesel operates on a two-stroke cycle. When the piston nears the end of the power stroke the exhaust valve lets out burned gases and fresh air flows in at the bottom of the cylinder. The air is compressed on the next stroke and a power stroke follows

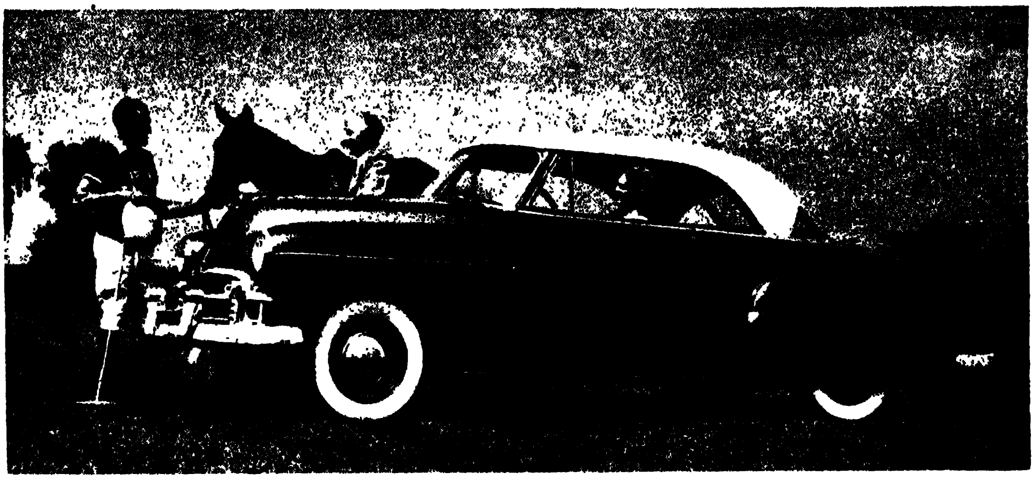


Photo courtesy General Motors

There is very little resemblance between this modern automobile and the first cars which frightened horses and people alike by their hiss and clatter in the early part of the century. The swift comfort of the modern car has outstripped even the brightest hopes of the automobile's inventors.

EVERYWHERE *on* WHEELS *of* AIR

The Epic Story of the Automobile

"WHERE do you guess the next one will be from, Daddy? *I* say New Jersey." The small boy was only five, but he would be able to tell where the next car came from by one glance at the license plate. This time his father, a little weary of the game, guessed Vermont, since that was the state they were in. But the next car was from California!

From everywhere in the land they come, going to everywhere else in unending procession. Until after World War I there were hardly enough automobiles to make a procession, much less make the game of "license plates" possible. Before 1914 children and grown-ups alike were impressed at just seeing an automobile.

The first automobiles were really railroad locomotives made to run on an ordinary road instead of on tracks. A Frenchman named Cugnot (kü'nyō') was running one through the streets of Paris in 1770. He could make two and a half miles an hour, with luck, not counting the time he had to take out to get up steam. In 1802 Richard Trevithick, a big, rollicking man, took his cousin up to London from Cornwall in a steam "road wagon." By 1827—when a railroad had been operating between Stockton and Darlington for two years—there was a regular passenger service along some of the roads around London.

The steam buses on this line must have been queer-looking things. Inside there was room for six passengers, and fifteen more could perch about outside. Some sat over the hind boot, with the steam boiler and furnace under them. Back of them rose four flues carrying the smoke and fumes from the burning coke and charcoal in the furnace. This type of steam wagon made from ten to twenty miles an hour.

Of course people did not quite know what to make of this odd new affair. Sometimes it merely amused them:

"Instead of *journeys*, people now
May go upon a *Gurney*,"

they sang, making fun of the name of the inventor, Goldsworthy Gurney. But a good many people hated all machinery, partly because it often threw them out of work. Once when Gurney himself was on a coach between London and Bath, an angry crowd from a village fair set upon the hated machine-

thing, yelling and throwing stones. The inventor was hurt. But of course mobs cannot stop machines from being invented and used.

The law, however, did come near stopping this particular machine for a while, at least in England. These big lumbering vehicles, which had to carry so much water and fuel, and which ran on such huge metal wheels, were as hard on the roads as the biggest modern truck. Besides, like the bus lines now, they took passengers from the railroads, and of course from the horse-drawn coaches too. So they had many enemies. Most of the passenger coaches were soon driven off the roads by heavy tolls—a kind of tax. Then in 1865 a "red flag law" was passed: a power-driven vehicle had to have at least three operators, could blow no steam off on the way, must not go faster than four miles an hour, and must be preceded by a man with a red flag or lantern of warning. That was enough to discourage any inventor in England.

But though these laws tied things up in England for thirty years or so, inventors were busy in other countries. It was having to use steam and therefore to carry so much fuel and water, like a locomotive, which made the early cars so clumsy. Nothing at all like the swift and compact modern automobile had yet appeared. But in 1885-6 Gottlieb Daimler (dīm'lĕr), a German, invented the internal combustion engine. This name really means an engine which works by a series of explosions inside it, or, in more scientific language, which changes chemical energy into mechanical energy. It is the mechanical energy which moves the car. The amount of gasoline necessary to make this energy in a machine is as nothing to the amount of water and fuel a steam engine has to carry around with it.

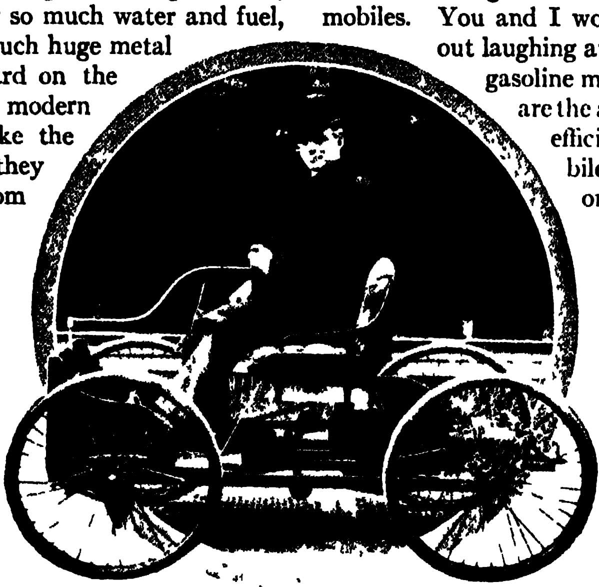


Photo by Handy

Here is the first automobile Mr. Henry Ford ever built. Coachmen and carriage drivers had to hold tight to the reins, for their terrified horses reared and shied when these horseless monsters went chugging by at what was then a tremendous speed!

Two enterprising Frenchmen, Panhard and Lavassor, bought the French rights to the Daimler engine and started to build automobiles. You and I would doubtless burst out laughing at sight of these early gasoline motor cars. But they are the ancestors of all of our efficient modern automobiles, whether regular or custom-made. Indeed, the people who saw the new machines spinning about Paris in the 1890's knew how wonderful they were: "It is no uncommon thing," wrote a correspondent of a London paper in 1895, "to meet on a summer day a little open vehicle flitting along without apparent means of motion, upon noiseless rubber-shod wheels, or panting forth a warning from a square-shaped box in front. To see it pass at racing speed—some of these little machines can spurt at twenty miles an hour—takes one's breath away at first."

About this time England repealed her red flag law and went to work perfecting the new device. In the United States, too, interest was rising and experiments were being made. Cars were built that ran with steam, with electricity, and with gasoline—"petrol" (pĕt'rōl), the English call it—but the gasoline type seemed to be the best. The Duryea brothers were the first Americans to make a gasoline car that actually ran. Only four gasoline cars existed in the United States in 1896—the Duryea's, one made by a German named Benz, one made by an American named Haynes, and a strange affair being driven about by Henry Ford. The last was creating so much interest that its owner had to chain it to a tree when he got out, for

fear it would be gone when he wanted to get in again.

For a good while nobody seemed to realize that these "horseless buggies" were going to be anything more than curious toys. The best ones were made abroad and cost around $5,000, and you could not get even the cheapest sort for less than $1,000. Besides, you never could tell whether they would really run or not. Many a man can remember the exultant whoop with which he used to whip the team past a bedraggled automobile stuck at the roadside with two rueful feet sticking out from under it where the owner was tinkering with its insides. These early experiences with automobiles brought forth a popular song entitled "Get Out and Get Under." It was not until around 1910 that one began to expect cars to run with only an occasional mishap, and that people began to buy a great many of them. In that year there were over 180,000 automobiles manufactured in the United States.

Somebody has said that it was Henry Ford who "put the mob in automobile." He certainly did have a good deal to do with the amazing number of cars which now began to run about over the United States. Long ago he had decided that "the car of the future must be the car of the people," and he had proceeded to make his cars cheaper and cheaper in order to sell more of them. In 1909 he put out the first cars of Model T, selling at about $900. Other cheap kinds followed, and many kinds that were not so cheap up to our most sumptuous limousines. With the boom times of the 1920's the number of cars manufactured in the country leaped high into the millions, and one political party even made a campaign slogan of "two cars for every family in the land." There are now more cars in the United States than telephones—a total of about 42 million.

A Gigantic Industry

Since America has taken so lustily to life on four wheels behind a bit of gasoline, it is clearly to the advantage of the manufacturers to make as many cars with as little effort and waste as possible. So the United States, manufacturing some eighty-five per cent of all the automobiles made in the world, has developed production plants so vast and complex that they are like great mechanical cities. You may pass through one of these huge factories and see your favorite car in every stage of its growth from scattered bolts and nuts and bits of steel to all its shining completed pride. Thousands of workmen help to build it, each doing some little swift and efficient thing as the machine which is going to be a car goes by on a moving belt or conveyor. Usually different sections are assembled separately and then put together afterwards. The plant will be laid out so that the parts shall waste as little time as possible in their journey and shall all begin to come together as the car nears completion. Sometimes the moving belts are as much as a mile long.

Certain of the great plants manufacture almost everything they need in making the finished car—castings of brass and aluminum, sheet-metal stampings and glass, even the

This great auto coach is very modern. It is just as luxurious as a railroad coach and offers means of swift transport.

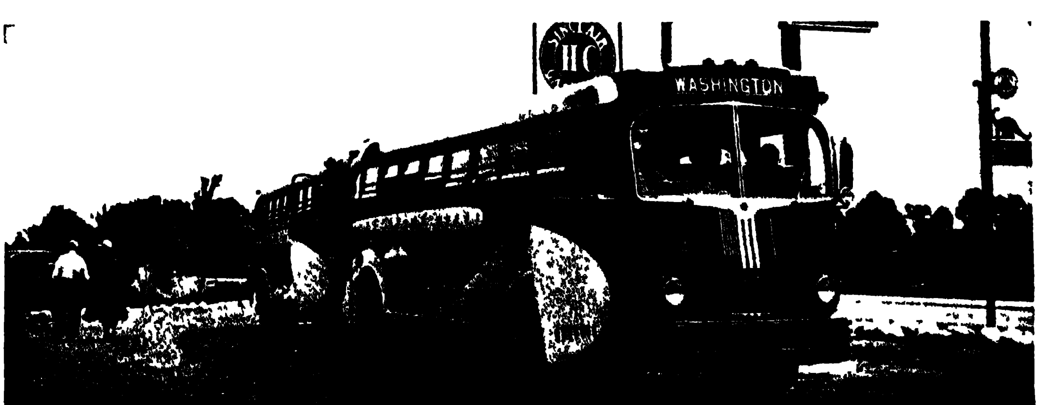
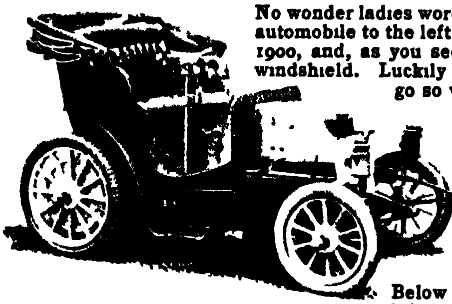
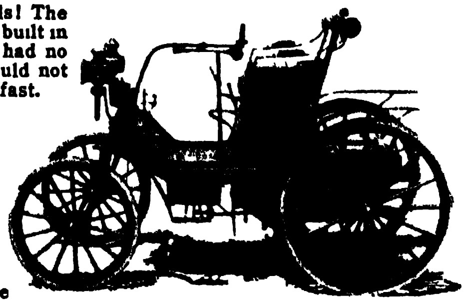


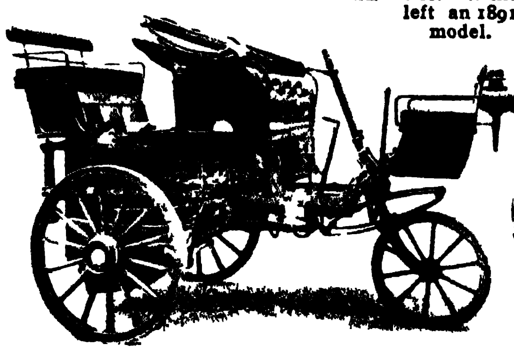
Photo by Keystone View Co.



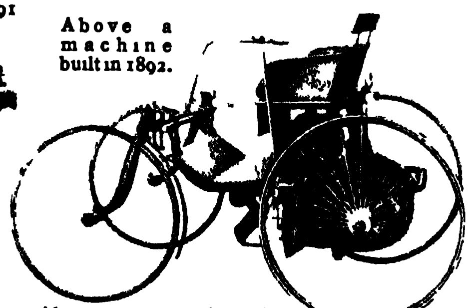
No wonder ladies wore veils! The automobile to the left was built in 1900, and, as you see, it had no windshield. Luckily it could not go so very fast.



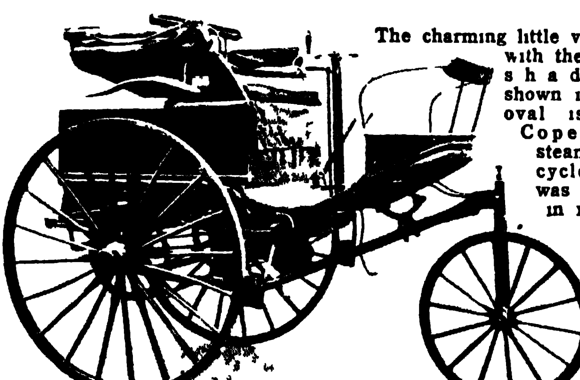
Above a machine built in 1892.



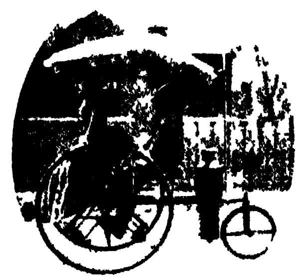
Below to the left an 1891 model.



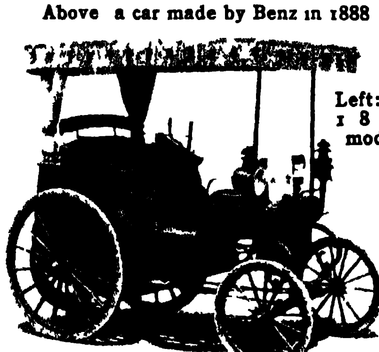
Above an automobile of 1889, with wire wheels like spider webs!



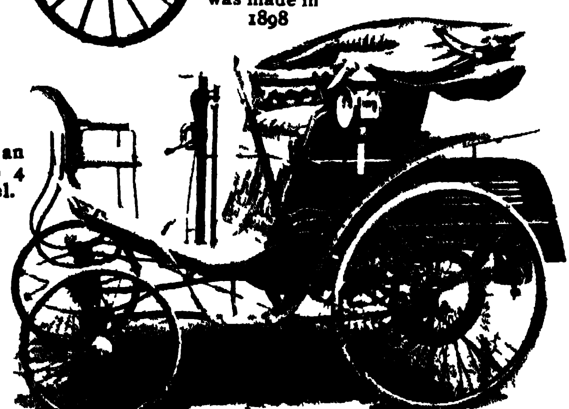
Above a car made by Benz in 1888



The charming little vehicle with the sunshade—shown in the oval is the Copeland steam tricycle, it was built in 1890



Left: an 1894 model.



The horseless buggy below was made in 1898

Photos by Deutsches Museum Science Museum and the National Museum

very tools the workmen use. Such a plant will have its own fleet of trucks to carry supplies and completed cars, or its own station if it uses the railroad. It may have many acres of ground laid out in race tracks and concrete hills on which to try out its cars to see if they work properly. It is almost sure to have its corps of trained research workers - maybe several thousand of them - to bring out new inventions in speed and comfort, or to watch the state of the market.

The Modern Motor Car

The cars turned out by these great factories, and by the smaller but no less effective factories of Europe, are often a joy to the eye as well as a convenience to the man in a hurry. The singing sweep of their long lines tells us of grace and speed. Power is in the lean steel body crouched low over the road We like the clean surfaces of the metal and the rich glow of the many colors our cars now have. For a long time designers foolishly tried to make an automobile look like a carriage; but an automobile is not a carriage, and in trying to make it look like one they could only make it look awkward and clumsy. The makers of the best cars realized this. So even the cheaper cars were made longer and lower and simpler to express the swiftness and power of the cunning machine. Makers also realized that safety was as important as speed, so they invented steel bodies, powerful brakes, and non-shatterable glass. This glass is made from a thin sheet of plastic pressed between two sheets of plate glass. If you strike this glass it cracks, but the pieces remain firmly attached to the plastic.

The Automobile in Commerce

We have been speaking of the ordinary automobile—or motor car, as the English call it—meant to carry from two to seven persons, and usually privately owned. As a glance at almost any stream of traffic will remind you, there are plenty of other kinds of cars. There is the "bus," or omnibus, which you see careening around the corner with a load of thirty or forty persons on their way to some neighboring town, or perhaps to a distant city. This sort of car is sometimes called a coach, and in Europe the open-top kind meant for tourists is called a char-à-banc (shă'ră'bôN'). Then there is the truck, heavy or light—called a lorry in England—which carries freight very efficiently, even if it is an annoying thing to get caught behind on a narrow road. Then there is the armored car—that is, a car made of bullet-proof steel to carry pay rolls and other large sums of money. The automobiles themselves, of course, are a multitudinous family - a great variety of styles of sedans, coupés, convertibles, station wagons, and jeeps.

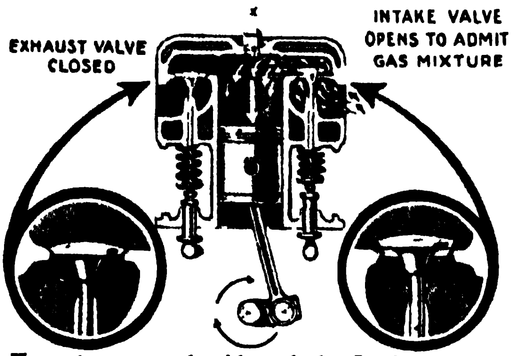
The Restless Age of Motors

So from everywhere to everywhere they pass in motley procession. It is rather hard now to imagine what the world would be without them. They have made it possible for the farmer to run to town after supper to a "movie." They have filled the mountains and beaches with week-end picnickers. They have snarled up traffic in the cities and even in the villages, and made it a real hazard to try to cross a through highway even in the country. They have laced the whole land together with strong bands of good roads. Certainly they have given thousands and thousands of us a chance to see what America is like—all of America, not the tiny corner we happen to have been born in. They have, in fact, helped to keep us the most wandering and restless of people. A brilliant English critic once said that Americans were forever having love affairs with different parts of their wide and various country. She meant that we are forever pulling up stakes—even if only for an hour or a week—and piling into the automobile and going somewhere else—to town, to the desert, to the mountains, to the sea, anywhere to get acquainted with a different part of the land. If that is so, it ought at least to help the different parts of the United States to know one another better. There is nothing like the procession of cars to make that possible. Let us hope that with knowledge may come understanding.

WHAT MAKES THE WHEELS GO?

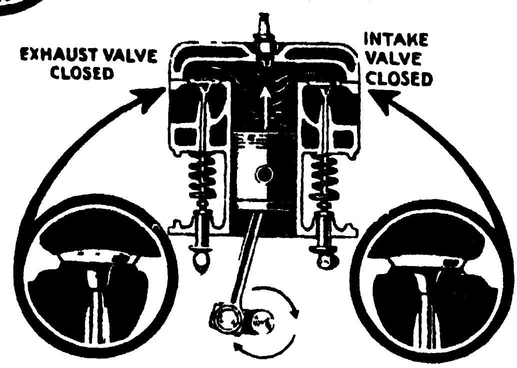
The automobile engine we describe here, operates under the principle of the four-stroke cycle. By "stroke" we mean the upward or downward movement of a piston in its cylinder. The piston is attached to one end of a connecting rod. This is a metal rod the lower end of which is attached by a bearing to a crank. As our pistons move up and down in the manner we are about to describe, the connecting rods move with them, and the rods, in turn, push the crank so that the crankshaft revolves. When the piston makes one stroke, either up or down, the crankshaft moves half way around. Thus when the four strokes are completed, the crankshaft has made two revolutions.

INTAKE STROKE

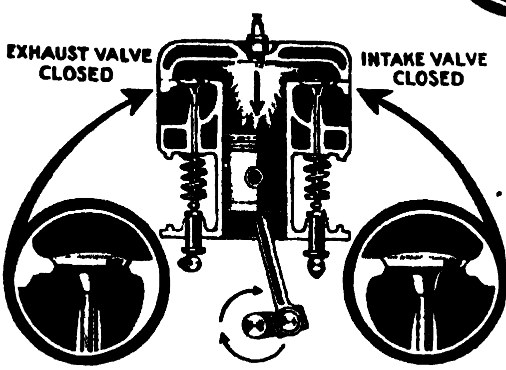


No motor can work without fuel. So the first stroke of the cycle takes in fuel; it is called the intake, or suction, stroke. As you can see in the diagram above, the intake valve is open and the exhaust valve is closed. A mixture of gasoline and air is sucked into the cylinder from the intake valve as the piston moves down. The next stroke, which is called the compression stroke, is shown in the diagram to the right. The piston is moving up, and both the intake and exhaust valves are now closed. The mixture of gasoline and air which fills the cylinder has no means of escape and is forced into a much smaller space than it occupied before.

COMPRESSION STROKE

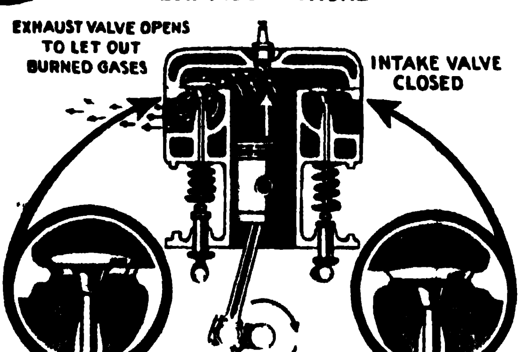


POWER STROKE



The third stroke in the cycle is called the power stroke. A spark, from the spark plug you see above the cylinder, ignites the mixture of "gas" and air, causing it to expand rapidly. It needs more room, but where can it go? Both the intake and the exhaust valves are closed. It moves down, and pushes the piston before it. On another page we shall explain how a spark plug works, and how the gasoline is brought from the gasoline tank and mixed with the proper amount of air in that part of our automobile which we call the carburetor.

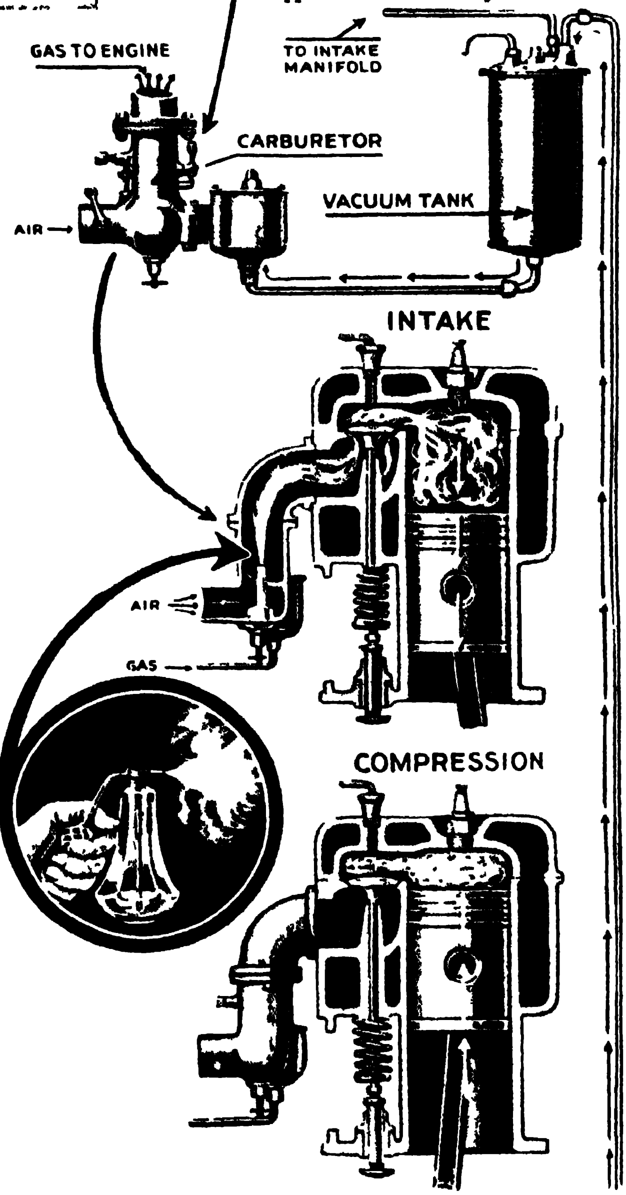
EXHAUST STROKE



The exhaust stroke is the last stroke in the cycle. The piston moves upward and the exhaust valve opens to allow the burned gases to escape. The cycle is completed and the engine is ready to begin all over again. This is the cycle which the piston must go through in order to make one power stroke. Now in the days when cars had only one cylinder, they chugged ahead in a very jerky fashion. But nowadays cars have 4, 6, 8, 12—even 32 cylinders. By arranging these cylinders so that they fire at regular intervals—so that at any given moment each one is going through a different stage of the cycle—the car can go forward with a smooth motion.

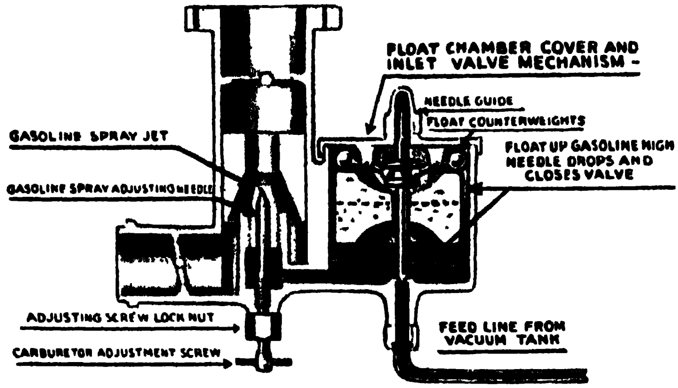
FROM TANK TO CYLINDER

The expression "step on it" is automobile slang. When we step on the accelerator, or floor pedal. we are doing just one thing—feeding gasoline to the cylinders. The more gasoline we feed to our engine, the faster it will go. But our engine will not take its gasoline "straight"; first the "gas" must be mixed with a proper amount of air. We have already seen what happens to the mixture of "gas" and air when it gets into the cylinders. Let us go back and see how it gets from the gasoline tank—which may be as far away from the engine as the car is long—to the cylinders, and what happens to it on the way.



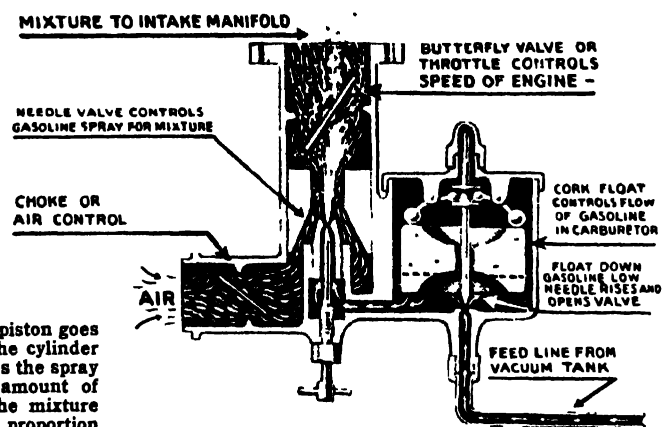
Gasoline will not run uphill any more than water will. So in the early days the gasoline tank was placed above the engine, so that the fuel would flow downhill into the carburetor. In later designs it was not always possible to place the tank in this position, so a pump was used to pump the fuel from the main tank into a smaller tank placed above the carburetor. To-day, while these two ways of feeding fuel are still in use, most cars are equipped with a vacuum tank. This is really just another kind of pump- the engine itself is the pump which creates the suction. The cylinders are so arranged that at any moment one or more of them is always sucking in fuel from the carburetor. This creates a partial vacuum in the intake manifold, so that if a hole were bored into this distributing device, air would rush in. But we do not waste its ability to suck. We run a small pipe from the intake manifold to a small tank, which thus becomes a vacuum tank. This vacuum tank sucks gasoline from the main tank as it is needed. The same suction which fills our vacuum tank is drawing quantities of air past the openings through which gas is flowing into the carburetor. The fuel is literally torn into minute particles forming a vapor or spray, exactly as perfume leaves a perfume atomizer. This air-gasoline vapor is sucked into each cylinder in turn through the intake manifold. So our gasoline has taken a rather lengthy journey from main tank to vacuum storing chamber to carburetor—where it is mixed with air—then to intake manifold and to cylinders. On the way it goes through a strainer where impurities, such as dirt and water, are removed.

Photos by Standard Oil Co. of N. Y.

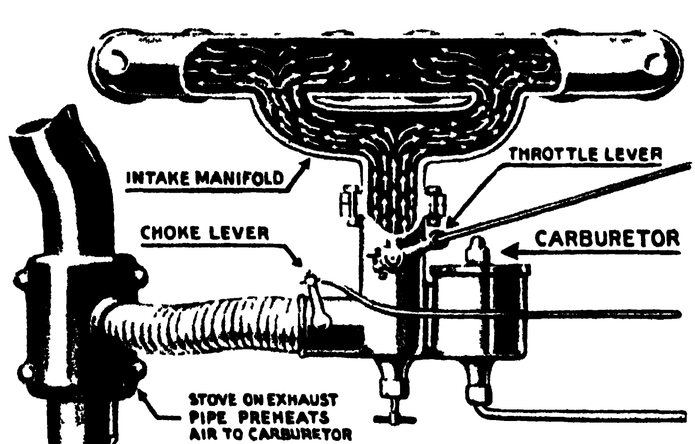


THE DEVICE THAT FEEDS OUR CAR A BALANCED DIET

Our car is very particular about its diet. It will take as much fuel as its cylinders will hold, but unless that fuel is a balanced mixture of gasoline and air, our car will not go properly--in fact it may not go at all! So we must install a carburetor which will measure the amount of gasoline that is going into the engine and mix it with the proper amount of air.



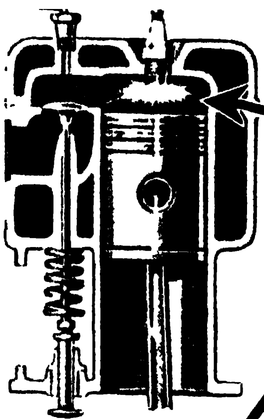
The gasoline flowing from our vacuum tank to our carburetor is first stored in a float chamber. As the gasoline rises in this chamber, the float rises. When the gasoline has reached the proper level, the flow is stopped by a lever which closes a needle valve at the bottom. At this point the level of the gasoline in the float chamber is even with the top of the spray jet in the mixing chamber. As the piston goes down on the intake stroke, the cylinder sucks in air. As the air passes the spray jet, it gathers up a small amount of gasoline, vaporizes it, and the mixture goes into the cylinder. This proportion of gasoline and air is regulated by a needle valve. We ourselves, of course, by means of the accelerator which opens or shuts the butterfly valve shown in the picture to the right, decide how much air the cylinders shall suck in and, consequently, how much of the gasoline-air mixture will go into our engine.



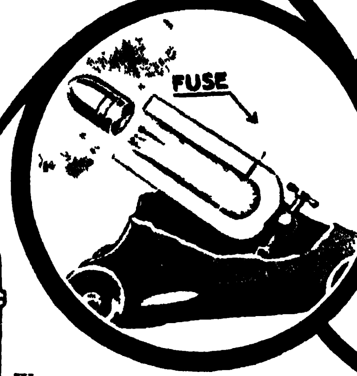
Sometimes it is necessary to use a very rich mixture in starting--that is, a mixture in which there is a greater proportion of gasoline. So we pull out the "choke," a valve which opens or closes the opening to the air intake pipe, and reduces the amount of air sucked into the mixing chamber. Many carburetors are fitted with hot-air stoves. We have said on another page that our engine needs a certain amount of heat to run with perfect efficiency. One of the things this heat does is to help in vaporizing the gasoline that is sucked into our cylinders. If our fuel is completely vaporized, it will burn with greater efficiency. So we utilize the heat of our exhaust pipe to warm the flow of air that is sucked into the carburetor.

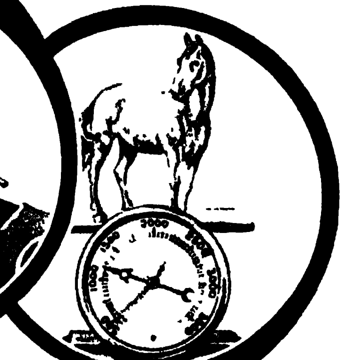
Photos by Standard Oil Co. of N. Y.

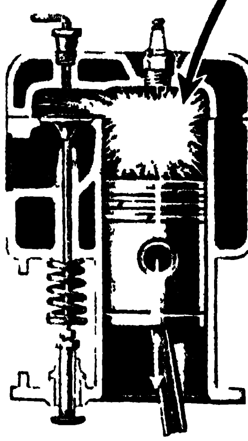
THE WELL-TIMED SPARK



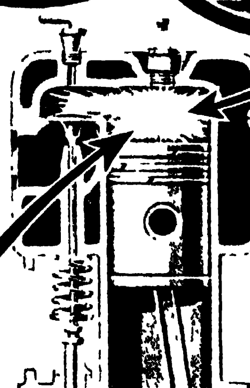
Our piston has gone through two strokes of the cycle. That is, it has traveled downward on the intake stroke and sucked gasoline and air into the cylinder; then it has moved upward on the compression stroke and pushed the mixture into a much smaller space. Now comes the spark from our spark plug. It sets the mixture on fire, causing it to expand rapidly and push the piston downward with a pressure of many thousands of pounds and with great speed. What is this spark and how does it know just when to ignite the mixture?







We may compare this action to that of a big gun. The cylinder is the gun barrel, the piston is the bullet, the mixture of gasoline and air is the powder, and the spark plug is the fuse.



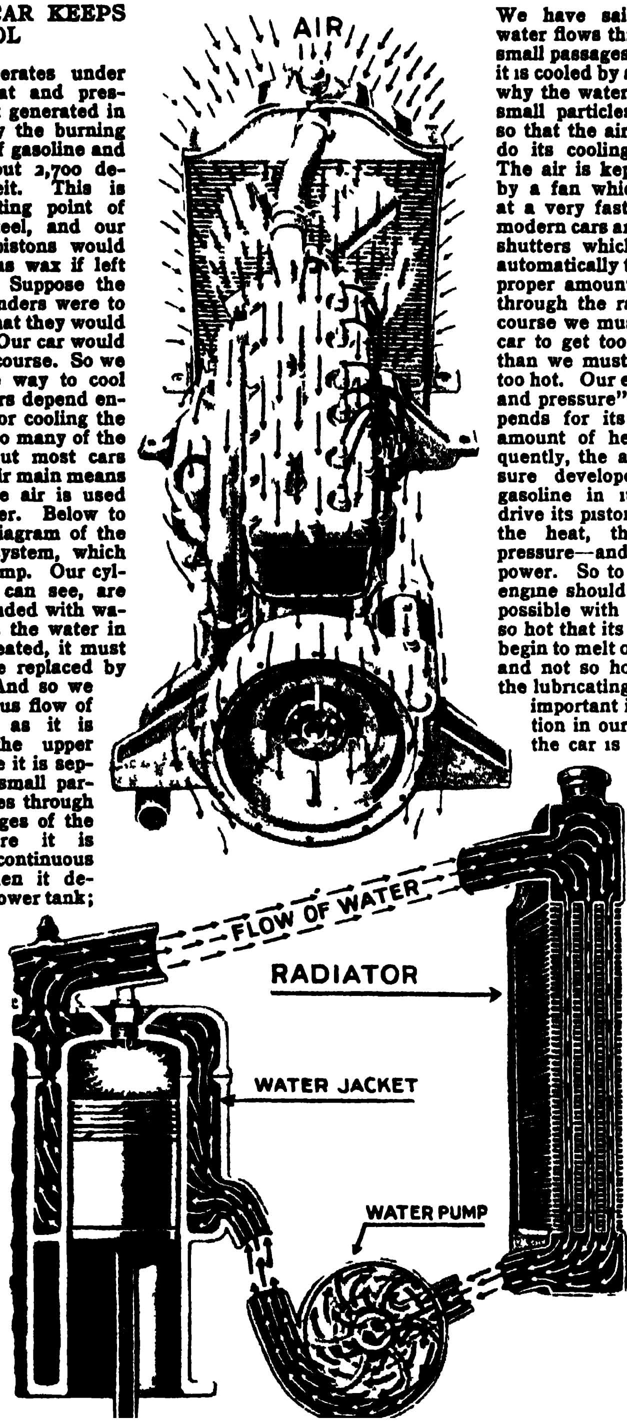
Now when we start our car we close the ignition switch. Low-voltage electricity from the battery passes through a circuit breaker which stops the flow of current at regular intervals. The impulses—or interrupted flow of current—pass through the ignition coil and are transformed into the high-voltage current required for ignition. From the ignition coil the impulses go to the distributor which distributes the electricity to the spark plugs. We may think of our distributor as the overseer who says, "Pass the next impulse on to the spark plug of the cylinder that is second from the end; that cylinder is just about ready for firing!" And he points his finger in the direction of the cylinder he is talking about.

Our car has four, six, eight, or more cylinders and every cylinder has its spark plug. Each cylinder requires its spark at a different time, and so the distributor is so arranged that it will deliver the electric current to the *right* spark plug at the right time. What makes the spark? As the electricity flows through the spark plug, it is forced to jump a gap, and that is where the spark occurs. We have said that the electricity came from a battery, but our battery is really a storehouse where we may store the necessary electricity for starting our car. Once our engine is running, however, and the flywheel is revolving, our generator will make electricity for our ignition and for our lights, and will replenish our battery.

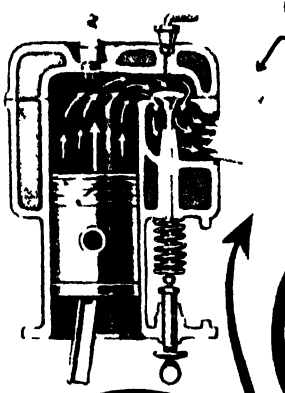
Photos by Standard Oil Co. of N. Y.

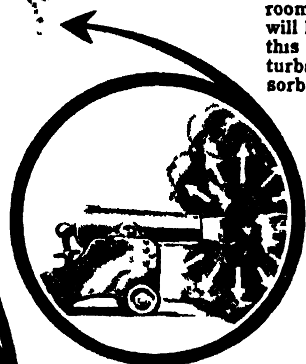
HOW OUR CAR KEEPS COOL

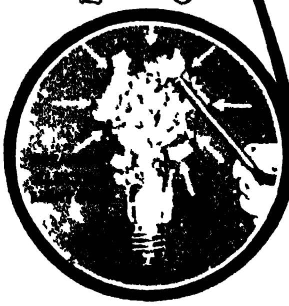
Our engine operates under tremendous heat and pressure. The heat generated in our cylinders by the burning of the mixture of gasoline and air reaches about 2,700 degrees Fahrenheit. This is above the melting point of cast iron or steel, and our cylinders and pistons would melt as easily as wax if left to themselves. Suppose the pistons and cylinders were to become so hot that they would stick together! Our car would not go at all, of course. So we must find some way to cool them. Some cars depend entirely upon air for cooling the engine, just as so many of the airplanes do; but most cars use water as their main means of cooling, while air is used to cool the water. Below to the right is a diagram of the water cooling system, which works with a pump. Our cylinders, as you can see, are partially surrounded with water jackets. As the water in this jacket is heated, it must flow out and be replaced by cooler water. And so we have a continuous flow of water passing, as it is heated, into the upper tank; from there it is separated off into small particles as it passes through the small passages of the radiator. There it is cooled by a continuous flow of air; then it descends into the lower tank; and from there it is pumped back through the water jackets. In most cases all of the water makes a complete circuit of the water cooling system every minute while we are driving our car at twenty-five miles an hour.



We have said that as the water flows through the many small passages in the radiator, it is cooled by air. The reason why the water is split up into small particles is, of course, so that the air will be able to do its cooling more rapidly. The air is kept in circulation by a fan which goes around at a very fast speed. Many modern cars are equipped with shutters which open or shut automatically to allow only the proper amount of air to pass through the radiator. For of course we must not allow our car to get too cold any more than we must allow it to get too hot. Our engine is a "heat and pressure" engine. It depends for its power on the amount of heat, and consequently, the amount of pressure developed by burning gasoline in its cylinders to drive its pistons. The greater the heat, the greater the pressure—and the greater the power. So to be efficient our engine should be as hot as is possible with safety—but not so hot that its metal parts will begin to melt or stick together, and not so hot as to destroy the lubricating oil, which is so important in reducing friction in our engine. When the car is cold, as for example when we are first starting it, the automatic shutters on the radiator will be completely closed. Then, as the car warms up, they will open gradually.



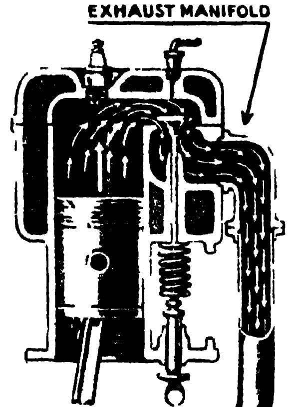


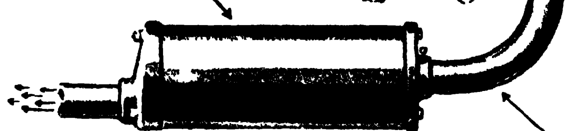


WHY OUR ENGINE PURRS

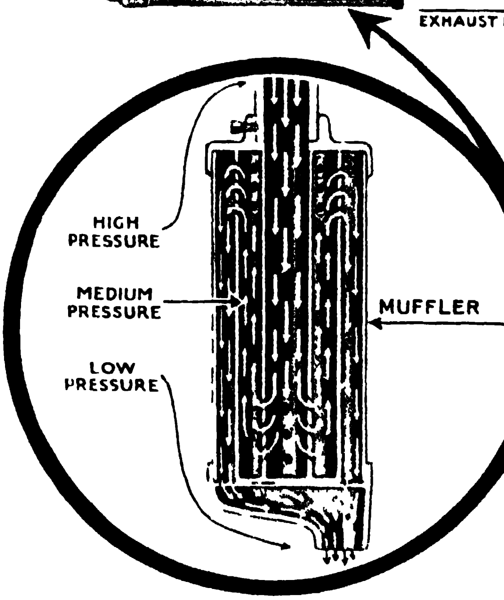
When we fire a pistol or break an electric-light bulb in the open air, we hear quite a noise; but when we do it in a closed room, a person who is not right in the room will hear very little noise. The reason for this is that air is very elastic. The disturbance caused by the explosion is absorbed, or taken up, by a rapid expansion or contraction of the air particles in the room, and very little noise is communicated through the openings in the room to the outside world.

What causes the noise? Gases from the gun expand in the air and then collapse very suddenly. Air rushes in to fill the space left vacant and the particles of air come together with a crash. When the partial vacuum of the electric-light bulb is destroyed, the air rushes in in the same way.

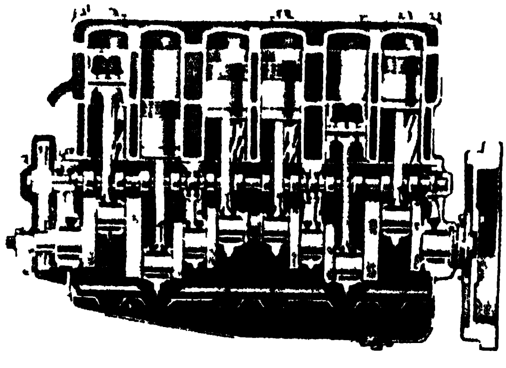


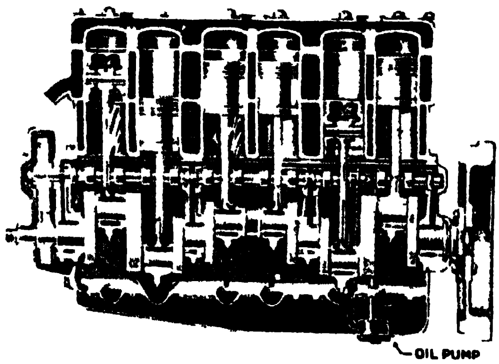


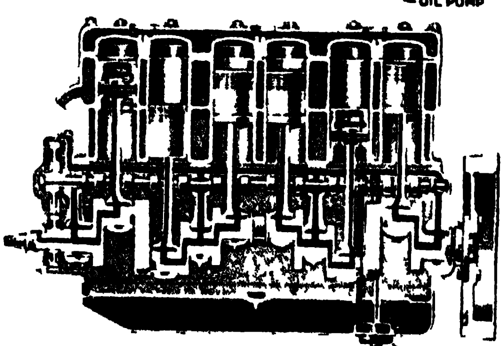
Now if we let the exhaust from the engine travel unimpeded through a straight pipe connecting with the open air, the noise it will make, as the explosions from the engine reach the air in rapid succession, will be quite unbearable. For the explosions of the exhaust are like the explosion of a pistol. Burned gases from the cylinders are pushed out with violence and, as they hit the outside air and are quickly cooled, suddenly collapse; and the air rushes in to fill the space they have left. So we must give the exhaust a room of its own—or rather a house, made up of tortuous hallways like a labyrinth. The exhaust gases reach this labyrinth in a very excited state; but as they are made rapidly to change in volume and in direction, they become less and less agitated, and when they finally get to the small pipe which takes them to the open air, they have become quite subdued. This house with the labyrinth of passages is called the muffler. The picture on the right shows you how the muffler is attached to the exhaust manifold. You must realize, of course, that the exhaust pipe which connects the two is almost as long as our car. In the circle is a diagram showing how the muffler is divided up into many little passages. The arrows show how the exhaust travels through these passages.



Photos by Standard Oil Co of N Y.

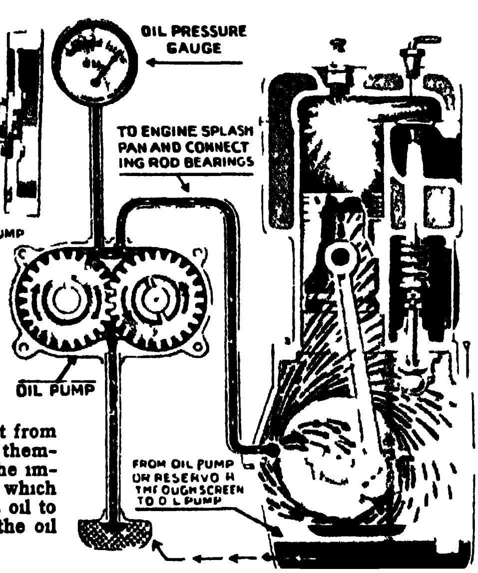






OUR ENGINE ITSELF

The object of our engine is to turn the two drive wheels usually the two rear wheels of the car How the engine power is transmitted from the flywheel to the *rear* wheels, has been explained on other pages. On this page we are concerned with the moving parts of the engine itself. The pistons, confined in their cylinders, can move only up and down The flywheel, which is attached to one end of the crankshaft and is shown in cross section in each of the drawings to the left, has a heavy rim which tends to keep the wheel revolving at a constant speed once it is set in motion This flywheel receives its impulses, or pushes, in sudden shocks as the result of the downward push, or "power stroke," of the piston on the crank It constantly receives these sudden shocks, and its duty is to smooth them out and deliver the energy of the shocks in a smooth turning motion to the driving mechanism of the car The flywheel has another equally important duty It must carry the piston through the remaining three strokes of the piston's cycle the exhaust stroke, the intake stroke, and the compression stroke The picture to the left shows you how the pistons fit into the cylinders and how the pistons are attached by bearings to the cranks, or turning arms, of the crankshaft The crankshaft, as we have said, turns the flywheel The flywheel operates the transmission which causes the drive shaft to turn at different speeds according to the gear arrangement used The driveshaft turns the axles, which are at right angles to itself, through a series of gears which are called the differential And so our car is rather like the "house that Jack built," for every part is dependent on another part and all parts work together

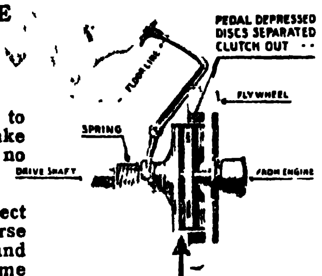


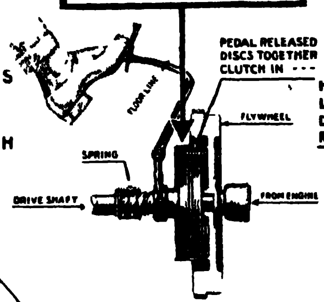
Our car is lubricated by means of a pressure system A pump forces oil under pressure to all parts of our engine where it is needed that is, to all the moving parts of our engine Oil reduces friction and heat in our motor, allowing the surfaces to move freely one against another Without oil the parts of the motor would bind and stick together so that it would be impossible for the engine to turn over The oil forms an actual film separating one part from the next, and is quite as important as the parts themselves. To the right is the pump which does the important work of lubricating, and the oil gauge which indicates the pressure at which the pump feeds oil to the engine Above are pictures showing how the oil is forced through the engine

Photos by Standard Oil Co of N J

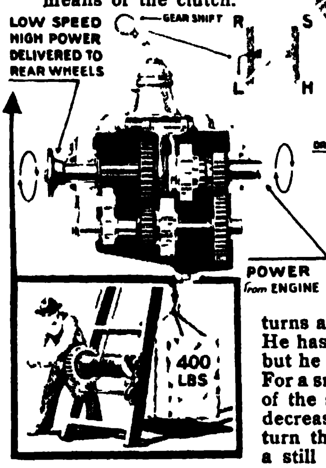
THE GEARS THAT CHOOSE THE SPEED AND THE CLUTCH THAT MAKES CHOOSING POSSIBLE

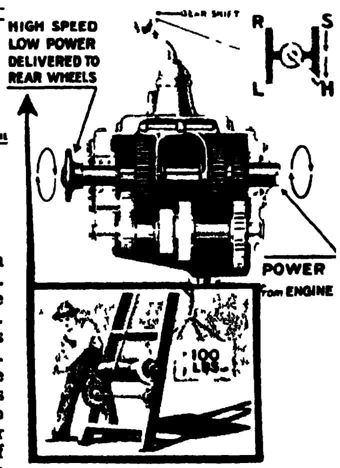
A running motor with no way to apply the power it develops to make it turn our wheels would be no use to us at all! And so we have a clutch which makes it possible to connect or disconnect our engine power. For of course we must be able to stop our car and keep the motor running at the same time; and we must be able to select our speed. Most modern cars have three speeds ahead first, or "low"; second; and third, or "high" —and one speed in reverse. Now, in order to make use of our various speeds, we must first disconnect the engine power by means of our clutch, then shift to a combination of gear wheels which will give our desired speed, and then apply our motor again by means of the clutch.



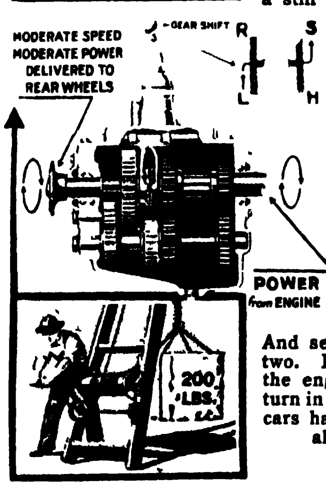


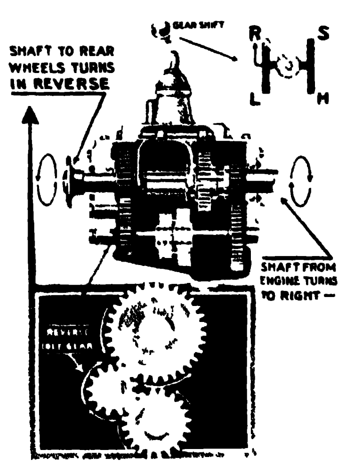
To the driver, the clutch is just a pedal he pushes upon when he wants to shift gears or stop his car. Very few people know what the device itself looks like or how it works. Place a silver dollar between two fifty-cent pieces and hold the three firmly together. Now try to turn the dollar and you will see that, with only a little pressure holding them together, it is hard to turn the dollar without turning the fifty-cent pieces with it. Our clutch works upon the same principle and depends upon friction for its hold. Engaging or disengaging the clutch is simply a matter of clamping firmly or unclamping a number of "disks" which are fastened, some to the flywheel and revolving with it, and some to the transmission. When they are all clamped together, they will all revolve with the flywheel.



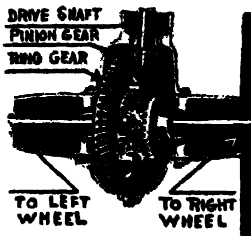


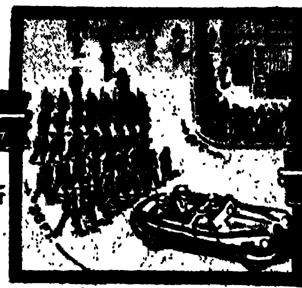
Our transmission is very much like a man operating a derrick. When he lifts a heavy load he turns a little gear against a larger one. He has to turn the handle many times but he has a great deal of lifting force. For a smaller load he increases the size of the small gear. His lifting force is decreased but he does not have to turn the handle so many times. For a still smaller load, he uses gears of equal size, turns the handle fewer times, and has even less lifting force. In each of these cases he has used the same amount of energy. Now the engine always has the same power, but by hitching this power to different sets of gears we can make it do different things. "Low" gear, for example, starts our car from rest or pulls us up a very steep hill. Once moving, "high" gear will pull our car along the highway at a great rate—but of, course, we couldn't use it for starting. And second gear is just between the two. Reverse gear does not reverse the engine. It makes the driveshaft turn in the opposite direction. Today's cars have improved synchromesh and all-automatic transmissions.



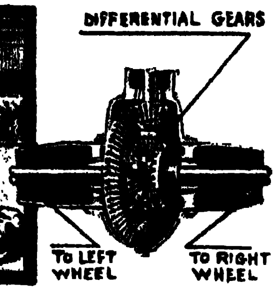


Photos by Standard Oil Co of N. Y.



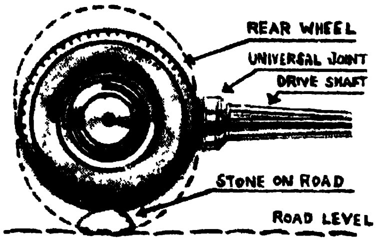


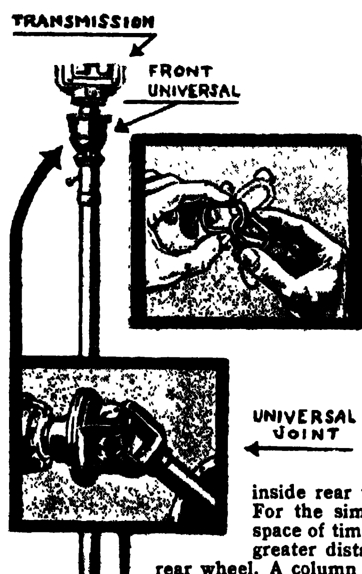
In turning a corner the wheels on the outside of the curve have to go a greater distance than the inside wheels do

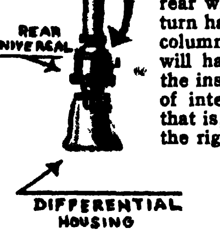


DEFYING A BUMPY ROAD

If our driveshaft—the long shaft shown at the right, which relays the power from the transmission to the rear axle—were a completely rigid piece of mechanism, it would soon go to pieces. For every time our car goes over a bump in the road, the driveshaft must change the angle at which it delivers the power to the rear wheels; and so, of course, it must be flexible. Our legs and arms have joints to make them flexible; so has the driveshaft. In some cars the driveshaft has one joint and in other cars it may have two. To the right is a diagram which shows how the driveshaft changes its position as our wheel goes over a stone. Below this diagram is a picture of the driveshaft with its "universal joints," and a "close-up" of one of the joints. As you can see from the "close-up," the universal joint can turn at an angle just as the links of a chain can. There are other devices which, if not quite so essential to the actual driving of our car, are very necessary to the comfort of the passengers. There are, for example, the four springs which are attached to the axles and which support the body of the car. In combination with the shock-absorbers—which keep the springs from throwing anyone in the car too far or too suddenly—they save the passenger many a painful jounce. Then, of course there are the rubber mountings—a series of cushions on which the engine may be mounted—which prevent us from feeling the engine vibrations. And last, but not least, there are the pneumatic tires which, more than any other factor, have made the automobile possible.







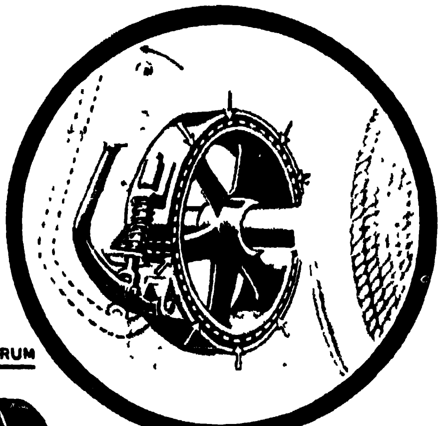
HOW OUR CAR TURNS CORNERS

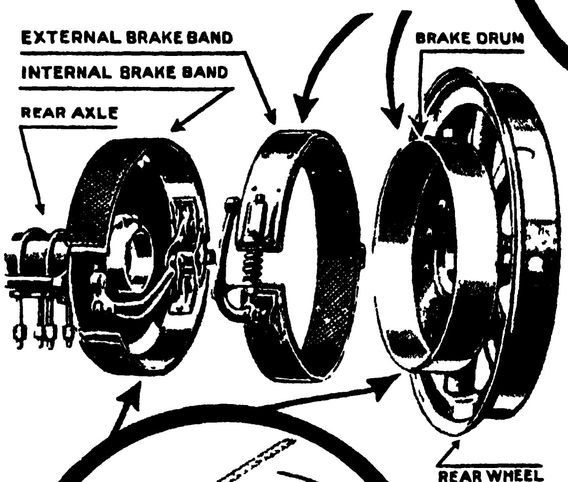
The differential is a fascinating bit of mechanism which has two very important jobs to do. Its first job is to direct the flow of power from the driveshaft at right angles to the rear axle. Its second job is to allow the inside rear wheel to go around more slowly than the outside rear wheel when the car is rounding a turn. It is easy to see why the first job is important, for your car may have as much power as you like but if that power is not hitched up to the wheels in some way, the car will not be able to budge an inch! Now the driveshaft, as you know, relays the engine power from the transmission to the differential. Above to the left is a picture that shows you how the pinion gear at the end of the driveshaft meshes with the ring gear to direct the power which, relayed through the differential gears, will turn the two separate axles at right angles to the driveshaft. And each axle turns its own wheel. The second job of the differential is not quite so easy to understand. Why should the outside rear wheel go faster than the inside rear wheel while rounding a turn? For the simple reason that in the same space of time the outside rear wheel has a greater distance to cover than the inside rear wheel. A column of soldiers marching around a turn has the same problem, and in order to keep the column even and in step, the soldiers on the outside will have to take much longer steps than those on the inside. The differential is a clever arrangement of intermeshing gears which work automatically—that is, they allow the rear wheels to turn at exactly the right relative speeds, no matter whether our car is making a wide or a sharp curve.

Photos by Standard Oil Co. of N. Y.

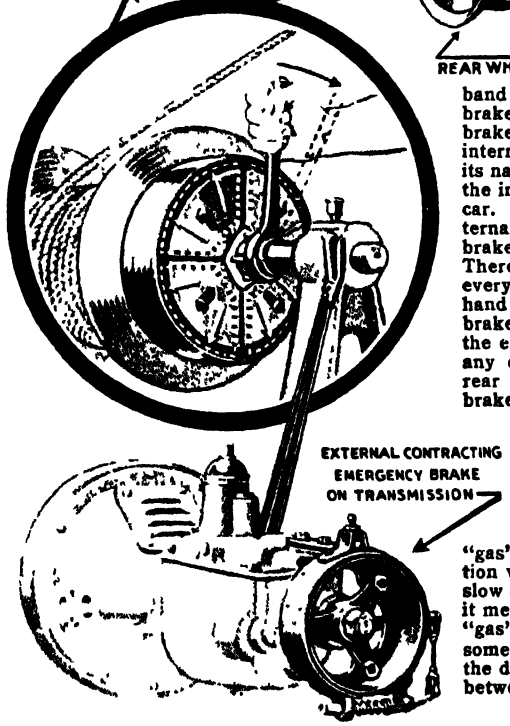
THE BRAKES THAT MAKE DRIVING SAFE

If we did not have some means of stopping our car or slowing it down, our driving days might soon be over.· We should find ourselves—if there were anything left to find!—in a ditch or over an embankment in no time at all. In the early days of automobiling, when cars chugged along at all of fifteen miles an hour, braking was not so much of a problem. But as cars became faster and more powerful, brakes had to be made that would be stronger and more dependable. And that is why most modern cars have brakes on all four wheels instead of having only two brakes—one on each of the rear wheels.





Now when you are coasting down a hill in an "express wagon" or "scooter," the best way to slow down is to drag your foot along the ground and let friction do the rest. Friction is what slows the car down, too, only the friction is brought about in a rather more complicated way. First we must mount brake drums on our wheels. Brake drums, as you can see from the picture at the left, are rather like saucepan lids made of metal. Inside or around the outside of each drum we put a metal brake band. These bands, labeled "internal" and "external" brake bands, are shown in the picture to the left. Now the internal brake band, as you can see, is covered with an asbestos fabric. The external brake band is lined with the asbestos fabric. These two brake bands are used in two different kinds of brakes. The internal brake band is used in the internal expanding brake, which does exactly what its name suggests; the brake band expands against the inside of the brake drum and friction stops the car. The external brake band is used in the external contracting brake; it contracts around the brake drum and, by hugging it, stops the car. There are, as you probably know, two brakes on every car—the foot brake and the emergency, or hand brake. In most cars to-day both of these brakes are internally expanding, but in some cars the emergency brake is externally contracting. In any case, the emergency brake acts on the two rear wheels only. There is still another kind of brake which works on the driveshaft instead of on the wheels. This brake, called the transmission brake, is shown in the picture to the left. Now the engine will do a certain amount of braking itself, if you cut off the supply of gas. This is because there is some friction in every part of the car and it takes a certain amount of "gas" to overcome this friction. This braking action works to our advantage only as it helps us to slow down when we want to. But in driving ahead, it means that we must always be supplying enough "gas" to overcome the engine friction. Nowadays some cars are equipped with a device that allows the driver, at any moment, to sever the connection between engine and wheels and coast ahead with what we call "free wheeling."



Photos by Standard Oil Co. of N. Y.

TRANSPORTATION

Reading Unit No. 17

COME AND SAIL ON AN OCEAN GREYHOUND

Note: For basic information not found on this page, consult the general Index, Vol. 15.

For statistical and current facts, consult the Richards Year Book Index.

Interesting Facts Explained

How trunks are loaded on a steamship, 10-294

How a ship gets ready for sailing, 10-295-96

Out to sea on a modern ship, 10-297-98

How landlubbers can get their sea legs, 10-299, 304

How time is kept on board ship, 10-300

What the boiler room is like, 10-300

Life aboard the ocean liner, 10-300-4

How the helmsman guides the ship, 10-304

Things to Think About

What makes us get seasick?

Why should we learn the art of tipping?

What changes have been made in boiler rooms of ships in recent years?

How does a ship's newspaper get the latest news?

Picture Hunt

How are people entertained on board ship? 10-301-3

What makes it hard for people on ocean liners to realize that they are not at a seaside resort? 10-293, 295-96, 301

Related Material

Which was the first steamship to cross the Atlantic? 10-221

How are the storage rooms on ships kept "as cold as Greenland"? 10-518

How can we tell whether or not a ship will sink? 1-471

How does the radio help a ship to find its exact position? 10-121

How do our ears make us seasick? 2-282-85, 10-304

Practical Applications

How do passengers spend their time on board the modern liner? 10-300-2

How can we make sure that we shall get the best possible service on board ship? 10-294-97

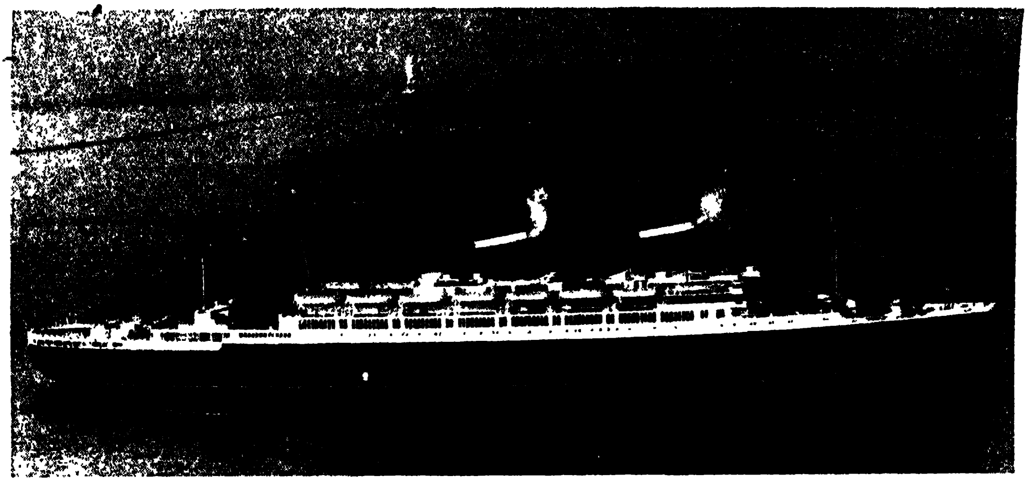
Leisure-time Activities

PROJECT NO. 1: Visit a steamship.

PROJECT NO. 2: List the chief liners and their owners.

Summary Statement

When we travel on an ocean liner, we find it so comfortable and pleasant that we sometimes find it hard to realize that we are not staying in a luxurious hotel at some popular resort.



Courtesy United States Lines

In spite of all newer inventions an ocean liner like this one can still give the traveler more comfort than any other kind of transportation. The "America," shown here, is for the first time sailing up New York harbor to her pier a brand-new ship. All the craft she passes will blow their whistles in salute.

COME *and* SAIL *on an* OCEAN GREYHOUND

Man Has Learned So Much about Mastering the Wind and Waves That Sailing in a Big Ocean Liner Is a Comfortable Adventure as Well as an Exciting One

"PIER 18. Sanconia Sailing at Noon To-day," read Uncle Tom from a big sign standing just outside the doorway of a long low building. "Everybody out!" he laughed.

For half a minute Ted and Jane were so excited that they could hardly move. But when Uncle Tom gave each of them a gentle tap on the back, they hopped out of the taxicab as quick as a wink. There was so much to see that they scarcely knew which way to look first. For of course they did not want to miss a single thing. Ever since they could remember they had dreamed of this very day. Even that Christmas two years ago when father had given them their shiny new bicycles, they had whispered to each other that they hoped some day to be even luckier. Not that they had said so, you understand, for they were as grateful and courteous as any nice boy and girl could be. But all their lives they had wanted above everything else in the world to go to Europe with Uncle Tom. And here they were at last, standing in front of the very pier from which they were to sail.

While Uncle Tom paid the taxicab driver, the children watched the people hurrying to and fro—other passengers also bound for Europe, and friends come to see them off.

Although it was two whole hours before sailing time, Uncle Tom said they were none too early. All really wise travelers get everything ready before the last minute if they are going abroad. Of course, father and mother and Aunt Janet had not come yet, but they were going to arrive a little later to bid the happy voyagers good-by. Uncle Tom said that meanwhile he would put everything in "shipshape and Bristol fashion." Certainly no one could beat him at that. For Uncle Tom was an old sea captain who knew all the ins and outs of ocean travel as few people ever learn them.

Ted wondered how the porters could carry so many heavy bags, and Jane was glad that she and Ted were taking the lightest baggage they could get along with. Uncle Tom had

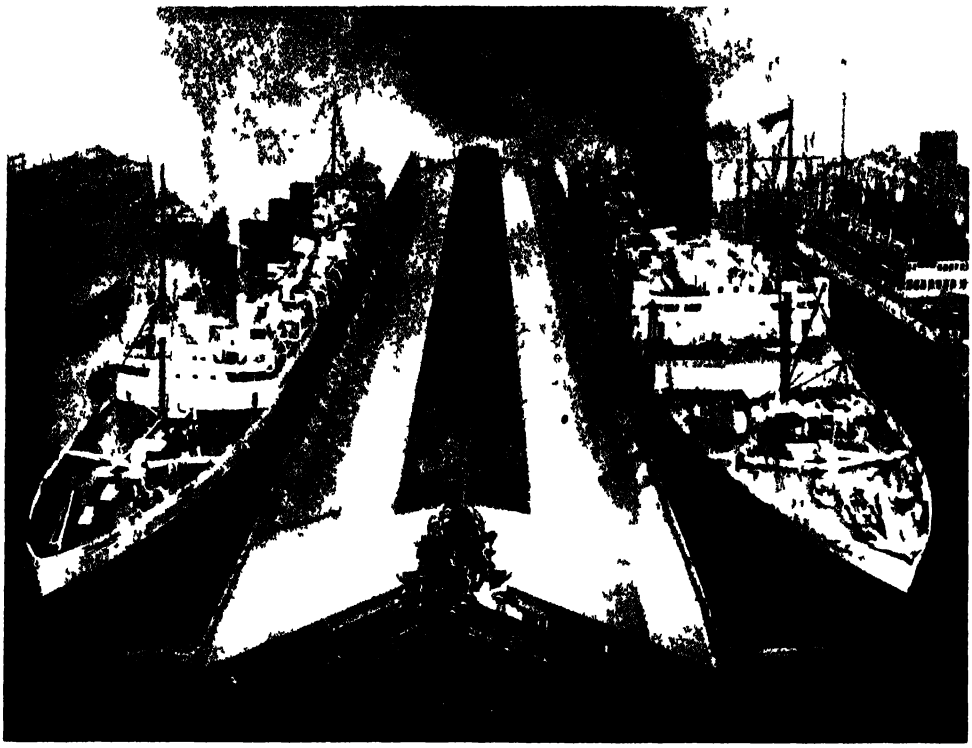


Photo by French Line

The taxi took Uncle Tom, Jane, and Ted past many piers like the one you see above There they saw great steamers docked, some ready for the long trip across the ocean Others were just landing their excited swarm of passengers amid a great confusion of baggage, porters, and customs officials

insisted upon that, for he had been to Europe many, many times, and he knew exactly how foolish it is to take anything you can do without

Loading Trunks on a Steamship

Just inside the entrance to the pier was a wide roadway along which trucks and taxi cabs were hurrying the great boxes and heavy trunks that were to be put into the hold of the "Sanconia" On either side were two flights of stairs, and between them was a great moving belt very much like those Ted and Jane had seen in the power plant at home, but a great deal wider As it crept upward like a great crawling snake, it carried suitcases and traveling bags, small boxes, packages, and even trunks It was certainly a labor saver, as anyone who has ever carried a heavy load up a long stairway will agree

The porter whom Uncle Tom had asked to carry their bags followed close at their heels When he had put their baggage on the moving belt, or freight escalator, as it is called, Uncle Tom handed him fifty cents That was to pay him for his work which in this case had been very easy The bags were light and the distance short As Uncle Tom explained later, there is a great deal to be learned about "tipping" To tip too much is just as bad as to tip too little It tells the attendant right away that you are not used to traveling And since any traveler's comfort depends to a great extent upon the service he gets from attendants, it is really important to learn the art of tipping at the outset

A Tip for the Porter

At the head of the stairway another porter took the bags from the escalator and put them on top of his small truck, already piled high with the bags of other passengers It was his business to wheel them along the

pier to a place near the boat, where one of the baggage stewards would take charge of them. He, too, would receive a quarter from the pocket that Uncle Tom had so thoughtfully filled with change.

Walking along the great pier, the children saw sights such as they had never seen before. Through an opening at the far end they caught a glimpse of the mighty Hudson, with the tugs and steamers, freighters and ferries that were moving up and down, back and forth, upon it. Through the wide openings at either side they saw the hulls of great steamships. Uncle Tom said the one to the right was the "Sanconia." All about it people were hurrying up and down. Up the brightly-carpeted, canopied gangway hustled passengers and stewards, officers and visitors, deliverymen and messengers. Not far away stewards were placing baggage of all sorts in great nets in which it was later lifted aboard ship by means of ropes and pulleys.

Cunard White Star Photo

In this handsome writing room first-class passengers on the "Queen Elizabeth" write the innumerable letters that seem to be a duty on every voyage. This is the world's largest ship. She has a gross tonnage of 83,673 tons. Her overall length is 1,031 feet and her breadth 118 feet. She has fourteen decks and provides thirty-five public rooms for the comfort of her thousands of passengers.

Tidying up a Ship

"Another labor saver," said Uncle Tom. "And now let us look along the other side of the pier before we go aboard. The famous "Egeria" is docked there. She is the fastest boat afloat and one of the finest ever built. She came in only yesterday and will not be sailing again for four more days. That's why there are no people hurrying off and on. And yet, as you can see, all is astir on board. Painters and carpenters, engineers and inspectors, electricians and able seamen—all these and many others are putting her in order for her next voyage."

Walking back across the pier, Uncle Tom called a steward to take their baggage to their stateroom. As they went, he told the children of the other ways in which baggage may be handled. He explained how trunks and bags that will not be needed on the boat are stored in the hold of the vessel if marked "Not Wanted," and kept there until called for at the end of the voyage. He also told how those that may be needed on the trip should be marked "Wanted," so that they will be placed right in your stateroom where you may get at them whenever you like. And, of course, he again told the children how important it is that every trunk and bag be securely locked, strongly strapped or roped, and carefully tagged and addressed to its owner.

Soon they found themselves in front of "510," the stateroom that was to be theirs for the next six days. The children were surprised to find it so large and so thoroughly modern and comfortable in every way. It was beautifully furnished and spotlessly clean - quite as pleasant as the living room at home. A large bureau, two easy chairs, a dressing table, several mirrors, two cozy beds, and a sofa that could also serve as a bed, all made the room cheerful and homelike. In less than a minute all agreed that Jane would sleep in the bed nearest the win-

dow and Uncle Tom in the other bed, while Ted would use the sofa.

Sitting down on the edge of his own bed, Uncle Tom heaved a sigh and said that he was glad to have such a good place to sleep. As he explained to the children, sleeping quarters aboard ship had not always been so nice as this. Not very many years ago, when there was little but hard bunks, one above the other, even the weariest traveler had found it difficult to get the rest he needed. Now almost every convenience known to the home could be had in a stateroom aboard ship. Hot and cold running water, forced ventilation, electric lights, even an electric fan, were all to be found in the thickly-carpeted stateroom which was to be theirs for this trip. Of course they were lucky to be traveling first class, but Uncle Tom assured them that second and even third-class staterooms were far more comfortable than any staterooms used to be.

Photo courtesy Holland America Line

By no means all the staterooms on the "Nieuw Amsterdam" are so luxurious as this one, but in all of them the architect and decorator have made every effort to combine comfort and beauty. If you were sitting in this stateroom nothing around you except the porthole at the far left would suggest that you were at sea and not in a fashionable hotel. Cabins as expensive as this one are placed amidship, where there is least motion

While they were examining their new home, the steward appeared with a number of packages, all wrapped in gay paper and beautifully tied. With quick fingers Ted and Jane began to open them. There was a package of books from Aunt Janet, each bearing some sort of message wishing them "bon voyage" (bōN vwä′yä/h′). As Ted and Jane knew, that was the French way of saying "pleasant trip," and the words one always uses in sending greetings to a friend going abroad. There were also a box of flowers from Mrs. Wilson, Jane's favorite neighbor at home, a great basket of fruit and candy from father and mother, a large jar of hard candies from Cousin Ruth, and three pretty handkerchiefs from the Brown children. One of the packages, addressed to Uncle Tom, contained a small box of choice Havana cigars and a copy of the latest detective story—the gift of his old friend, Captain Robbins. Even more interesting were the three packets of steamer letters, each containing six letters, one for each day at sea. Ted wanted to open his at once, but Uncle Tom persuaded him to save them until later.

As they sat admiring their presents, mother, father, and Aunt Janet appeared in the doorway. Then, of course, there were shouts of greeting and "thank-you's," and a great deal of excited talk. When all the gifts had been shown, Uncle Tom rang for the steward and asked him to put the flowers and fruit in the refrigerator for a few hours. That would freshen the posies, he said, and "keep the cabin from smelling like a fruit store."

Tips Get Good Tables

It was then time to look after the many matters that all good voyagers attend to at the first possible moment. So off went Uncle Tom to secure their places in the dining salon (sä′lōN′). If he had told any of the officers who he was, he would surely have been invited to sit at the Captain's table, one of the honors on any ship; but Uncle Tom was on a real holiday and had brought no dinner clothes with him. Then, too, there were the children to consider, and this meant that he ought to have dinner as early as possible.

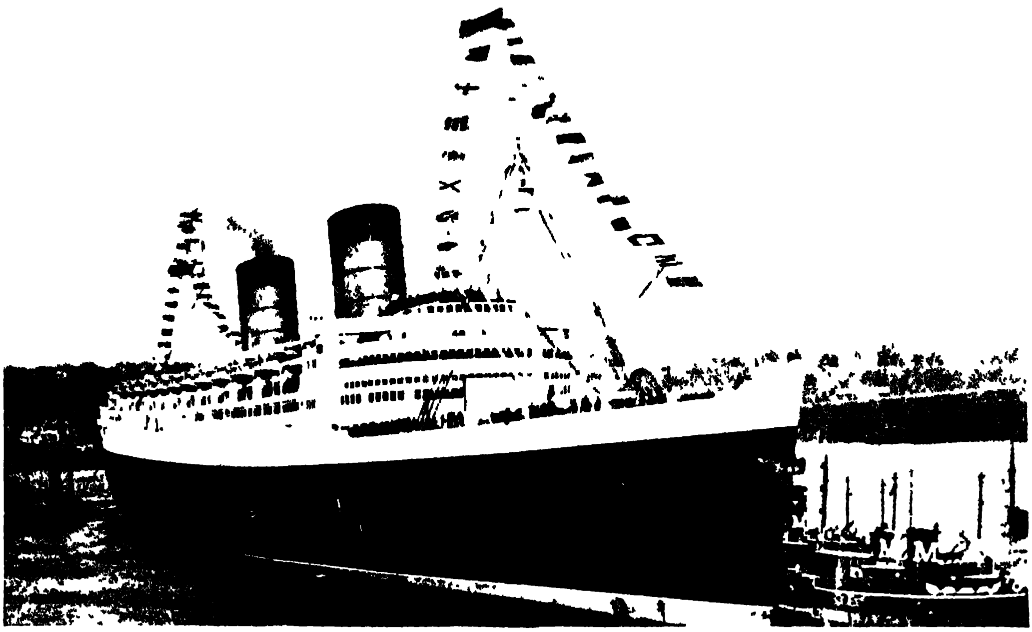


Photo by Cunard White Star Ltd

Blowing whistles, cheering crowds, the shouting of gay good-by's and of last-minute messages what a din accompanies the great ship as she slips gracefully away from the pier. Ted and Jane are leaning against the rail, frantically waving their handkerchiefs, but their faces have become a blur across the ever-widening strip of water which separates the stay-at-homes from those who are going out to sea.

each evening. The very way in which he asked for three places at "Table 18" "the first sitting" must have impressed the chief steward, for scarcely a minute passed before Uncle Tom had the proper checks in his hand. He smiled as he took them, for he knew that not all passengers find it so easy to get what they want. As he told father later, it usually takes a generous tip and a little forceful talk to get that.

Where to Have Your Deck Chair

Next came a trip to the chair steward, from whom Uncle Tom rented three deck chairs. Knowing that the winds from the north are very chilly as they blow across the sea, he selected well-protected chairs amidship on the starboard side. That would be the south side on the way over. He was also careful to see that they were far enough from any hatch, or companionway, to escape the traffic that would surely come and go up and downstairs. Handing the chair steward four dollars and a half, he tucked the receipts into his pocket, knowing that he might need them later on.

Then away he went to the bath steward to set a time for his own and the children's daily baths. He had heard too many people grumbling about the odd hours they had for bathing, and he was going to take care that they should all get their baths the first thing in the morning.

That done, he went to the purser's office and left a small package of valuables too precious to be carried about or left in his stateroom. He knew that it would be perfectly safe in the purser's strongbox.

And now that everything was arranged, he returned to the stateroom and suggested that they all go on deck where they could watch the other passengers coming and going.

"All Ashore That Are Going Ashore!"

How interesting it was! Some were laughing and gay; others sad and tearful. Stewards were rushing back and forth, officers walking up and down. The children had never before seen such excitement or heard so many different languages. Messages were being given in French and German, Italian and Spanish, and any number of other languages besides.

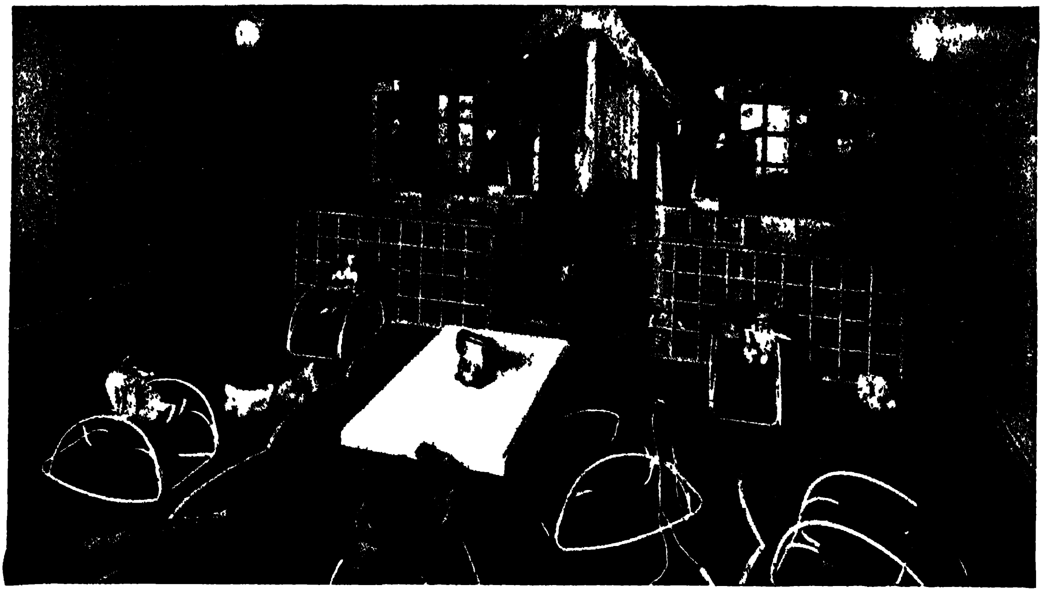


Photo by Cunard White Star Ltd

This charming little house with its interesting inhabitants is for the entertainment of the ship's younger passengers. The dolls and Teddy bears have short memories, and will easily form attachments for an entirely new set of people on each voyage. A supervisor will see to it that no one is unhappy or bored.

Then suddenly above all the hubbub a whistle sounded and an officer called out, "All ashore that are going ashore!" There was a rush of last-minute farewells and then the visitors all hurried off the boat.

The Greatest Thrill of a Sea Voyage

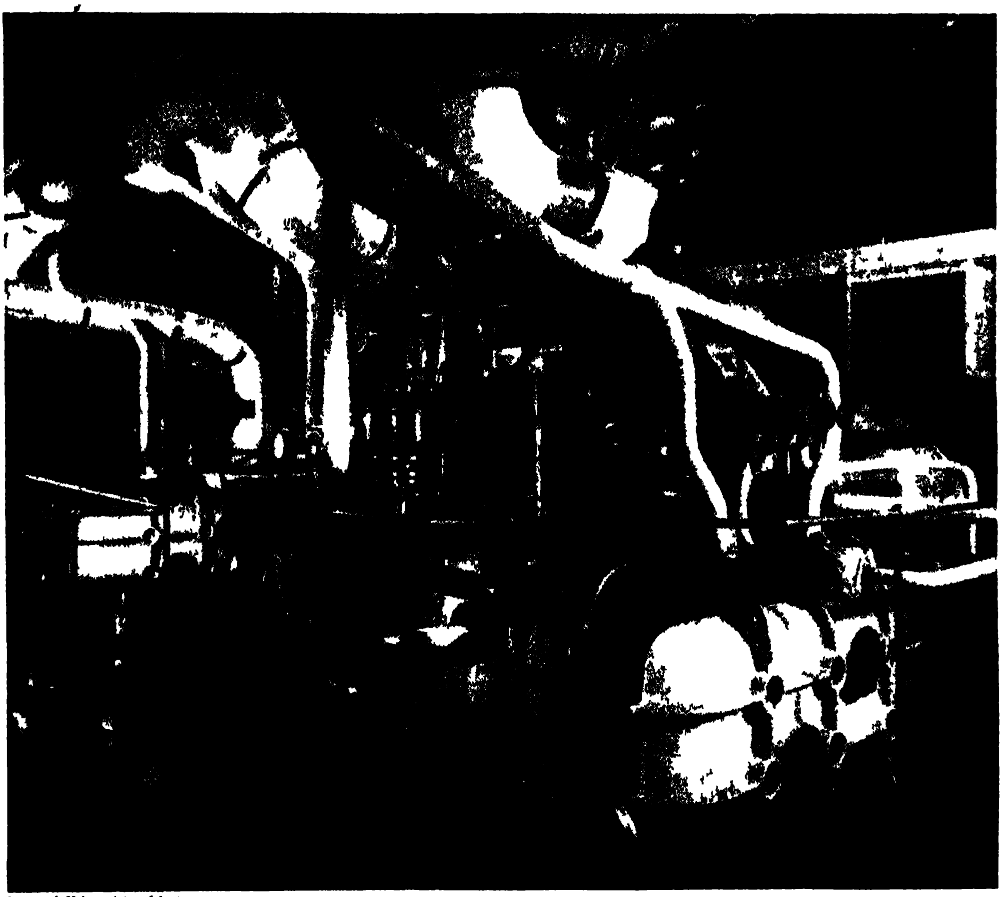
As they kissed mother and father and Aunt Janet good-by, Ted and Jane almost wished they were staying at home. But their sadness soon passed, for it was only a minute before they saw father waving his hat from the pier and mother smiling and waving her handkerchief. Ted waved the small flag he had put in his pocket, and Jane waved both hands as hard as ever she could. Everybody on the boat and the crowded pier seemed to be calling out final farewells and waving furiously. Rolls of brightly colored paper ribbon were thrown by many people on the pier, and some few were even caught by those on deck. It was like a shower of ribbons. Then the whistle sounded again, and the great ship began to move slowly away from the dock. The small tugs that pushed her from her mooring place steamed and puffed as they slowly nosed her out into the river and turned her about.

As soon as the "Sanconia" lay in the middle of the stream, her bow pointing down the river, the puffing little tugs backed away from her. At that instant the huge vessel quivered from stem to stern. It almost made the children fear something might be wrong. Uncle Tom, however, put them at ease by saying that the vessel's great engines had now been started and that under her own power she was ready for the long ocean voyage. As the "Sanconia" steamed majestically away, the friends on shore kept shouting and waving until they could no longer be heard, and at last faded from sight.

Out to Sea on a Modern Ship

But there was no time to be sad about that. One by one the great skyscrapers of the city were slipping past; then the islands out in the bay, the Goddess of Liberty, the forts that protect the harbor, and the lighthouses and buoys by which sailors guide their ships. All these things were so interesting that Ted and Jane had no time for thinking of anything else.

But Uncle Tom did suggest that they go to the writing room and send a little note to mother and father. If they put it in the



Cunard White Star Photo

The engine room of a great steamship is a maze of machinery all polished and shining with the parts moving at tremendous speed when the ship is in motion Their throb is felt in every fiber of her structure Here we show a section of the generator and main switchboard on the "Mauretania," a famous ship that did gallant service as a transport during World War II. She bears the name of a still more famous predecessor the finest ship afloat in her day That ship was scrapped in 1936 after nearly twenty years of service Oil burners like the "Mauretania" spare the lives of many a stoker of the type who served the old-fashioned coal furnaces

ship's post box within half an hour after sailing time it would go back to shore with the pilot boat when this took the pilot back to port, after he had guided the big ship out through the narrow winding channel of the harbor which he knew so well

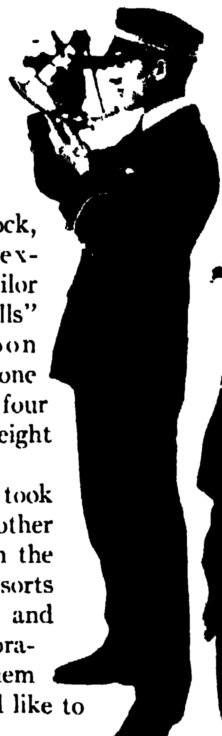
When their notes were written, Uncle Tom showed them their deck chairs Their names were already on the backs of their seats, as were those of all the other passengers who had rented chairs The wind was already getting a little chilly, and Uncle Tom asked a steward to bring them gay, warm steamer rugs Then he explained that the steward would put away the rugs each evening, but that they could always be had for the asking if one wanted to sit on deck

When the three were all wrapped up snug and warm Uncle Tom told the children a lot of things that all travelers need to know Above all, he said they must not watch the waves too much for the first few hours they might as well close their eyes while they talked Later they would walk up and down the deck until they were used to the roll and pitch and throbbing of the vessel In that way most of the landlubbers can get their sea legs and probably escape being seasick He also told them not to eat too much for the first day, and to get all the fresh air they could

In fact Uncle Tom seemed to have a thousand things to tell far more than Ted and Jane could remember when they got back

home and tried to repeat it all to everybody. And all the things they saw and heard were new marvels to them—from the number of languages the stewards could speak to the fact that they had to set their watches forward every morning to keep up with the sun.

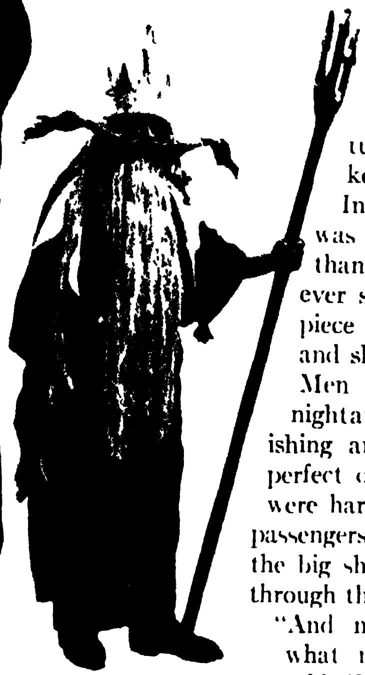
They were interested to know that aboard ship time begins at noon, that it is kept by striking bells every half hour, and that the day and night are divided into "watches" of four hours each. It was then one o'clock, and Uncle Tom explained that the sailor would call it "two bells" of the "afternoon watch." Half-past one would be three bells, four o'clock would be eight bells, and so on.



This young officer is "shooting the sun" which simply means that he is finding out the height of the sun above the horizon. He takes his measurements by means of a sextant, and when he has done some further problems in mathematics he knows the exact position of his ship upon the earth's surface.

Then Uncle Tom took them to see various other parts of the ship. In the library they found all sorts of interesting books and magazines, and a librarian ready to help them find what they would like to read.

They saw the handsome lounges where passengers sat and read, talked, or played cards, the beautiful big swimming pool, and the many shops where one could buy almost anything from a camera film to an evening wrap. With its barber shop and restaurant, florist and confectioner, the "Sanconia" was truly like a floating city.



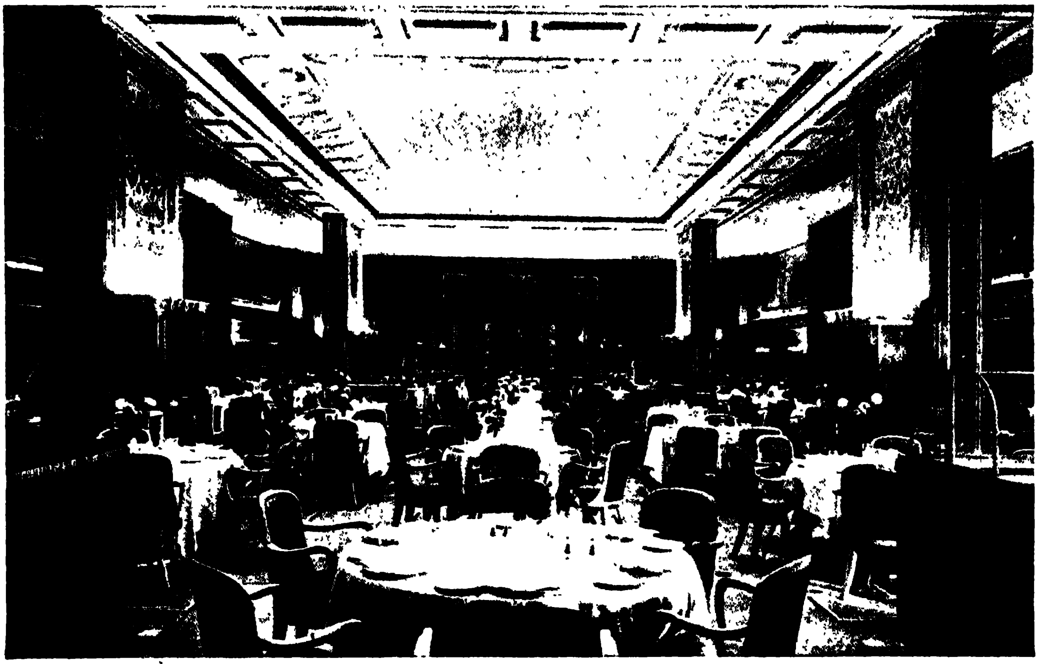
Photos by French Line and Hamburg American Line

Here is old Father Neptune himself, ready for the ceremonies which take place when a ship crosses the Equator. In the old days of sailing ships any sailor who had never crossed the Equator before, was brought before a member of the crew who was dressed as Neptune, god of the sea. The unhappy sailor had to submit to all kinds of playful but fairly businesslike tortures before the initiation was over; but after that he could call himself a true world traveler. Luckily for seafarers to-day, this ancient custom has been greatly modified, although "Neptune" may still hold court as a ship crosses the Equator.

Later on, when Uncle Tom discovered that the second officer was an old friend, he asked him to show the children the huge boilers that furnished the power for the ship's engines. And of course the Second Officer was glad enough to do it. Following him down flight after flight of steps, they finally reached the room where the great boilers were heated by oil burners. As he showed them to the children, the officer told them how much cleaner these burners are than the old coal grates that were used until only a few years ago. Until then hardworking men called stokers labored night and day, in a stifling temperature, shoveling coal into the great furnaces in order to heat the water in the boilers and so make the steam that turned the engines and kept the ship moving. In the engine room there was more big machinery than Ted and Jane had ever seen before, but each piece of it was as bright and shiny as a new watch. Men were working on it night and day, oiling and polishing and keeping it all in perfect order. All these men were hardly ever seen by the passengers, but without them the big ship would never plow through the waves.

"And now that you know what makes the ship go," said Uncle Tom, "let's get back to the lounge and listen to the band concert. There will be one each afternoon. Besides, we don't want to miss our afternoon tea. When the bugle sounds, that means food. You'll soon discover that eating is one of the things you'll do oftenest on this voyage. The salt air will keep you hungry most of the time." And they found it to be true!

After tea they went on another tour of inspection. This time they saw the brokerage office, where the latest reports of stock market prices are posted as they are received



In the ship's great dining room Ted and Jane could order almost any of the things they might have had to eat at a big hotel on shore. They were amazed to see how many different foods the ship's ice box held!

Photos by Cunard White Star Ltd.

On a ship's promenade deck passengers may walk or play games or just sit in the sun. In bad weather they have this comfortable lounge in which to read or talk with friends, safe from spray and icy winds.

by radio from New York, now many miles away. With these came all sorts of other news of what was happening on land—who won the baseball games, what the President and Congress were doing, and many another thing. Ted and Jane learned that there would be a newspaper every day during the trip—printed on the boat!

It was now time to get ready for dinner. Many of the people would put on evening clothes, but our three travelers were just out for a good time, and not for style, on this trip. Yet when the bugle sounded, Jane was in her pretty new blue dress, and Ted and Uncle Tom had on clean white shirts and dark suits. Even though they had taken tea only an hour or so before, they were as hungry as wolves. And the dinner was so good and plentiful that they found it hard to remember Uncle Tom's caution about not eating too much until they got used to the sea. They decided later that dinner was one of the pleasantest experiences of each day, for besides the mere delight of eating there were all the interesting stories with which everyone seemed ready to amuse his table companions.

The evening was pleasant, too. There was a concert in the lounge given by one of the passengers, who was one of the most famous pianists in the world. And after that there was dancing; and of course no healthy voyager would think of turning in before he had first done his mile around the deck. By the time they had done all that, Ted and Jane were more than ready for bed. As they fell asleep they were still thinking of their wonderful first afternoon at sea.

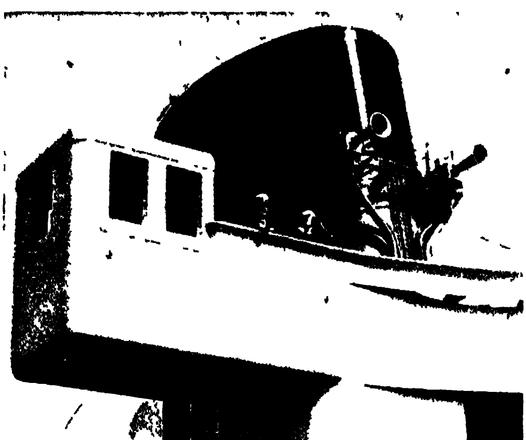


Photo by Cunard White Star Ltd.

This is the ship's "bridge," where certain of the ship's highest officers are always on watch to see that their vessel with its cargo of lives comes safe to port. In case of danger the captain will "take the bridge" and will never leave it until all danger is over. His meals will be brought to him and he will snatch only an hour of sleep now and then. On vessels of any size a public-address system will make it possible for him to issue commands by word of mouth to every post on the ship. If a ship goes down, the captain must be the last to leave her. And if he is a sailor who takes a deep pride in his profession he will prefer to go down with his ship. Fog is the sailor's worst enemy. The two horns on the great smokestack above will blow every two minutes if the ship runs into a fog on the high seas.

When the steward tapped at their door at eight the next morning, Ted and Jane did not feel the least bit like crawling out of their comfortable beds, but the sight of Uncle Tom putting on his last shoe sent them scurrying into their bathrobes and down the corridor to the bathroom. Since each passenger had only fifteen minutes for bathing, they knew that there was no time to waste. In a moment a good shower of hot salt water took all the sleep out of their eyes. They were not going to miss any chance of a shower like that on the trip. They told Uncle Tom the old ladies could have all the fresh water they wanted to experiment with the special soap that must be used with a salt bath.

They all took a few turns around the deck—six times around made a mile—and then to the steaming breakfast! After this began another busy and exciting day—walking and running round the various decks, basking in the sunshine, watching the great waves as the "Sanconia" plowed through them, playing deck tennis and shuffleboard and any number of other games, dancing—and of course forever eating.

There was bouillon at eleven o'clock, a "movie" and tea again in the afternoon, the band concert, more dancing at night, and another musical program by one of the talented passengers. A visit to the ship's kindergarten, where the smaller tots were being cared for by trained teachers, a trip to the well-equipped gymnasium, and a tour of the decks below, set apart for the use of second-class and third-class passengers, all came during the course of the day.

A MODERN STEAMSHIP

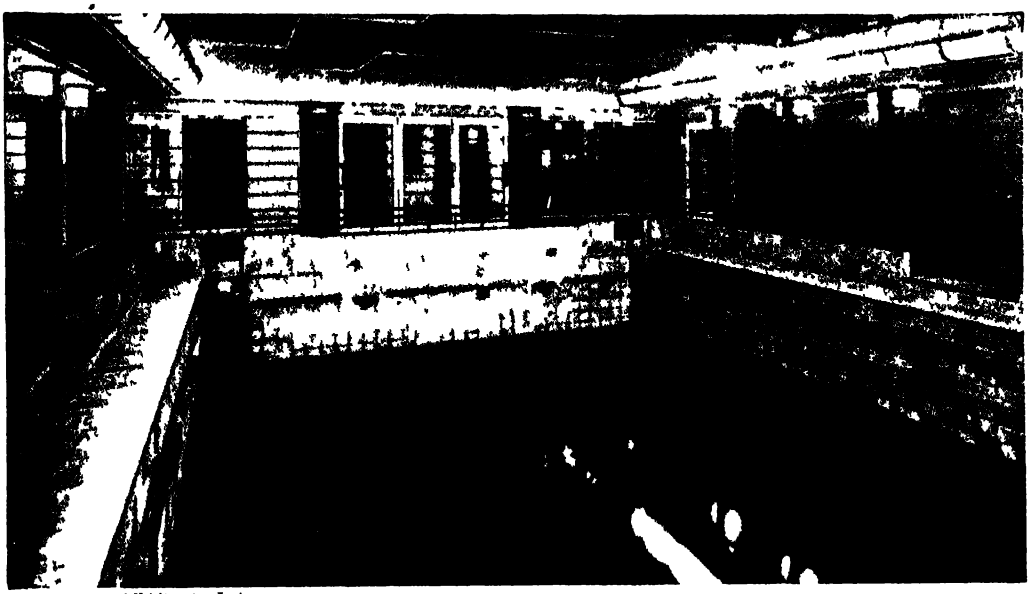


Photo by Cunard White Star Ltd

"Water, water everywhere" and a beautiful swimming pool besides, where anyone may take a plunge. This one is not unlike a Roman bath, but what a surprise it would have been to any ancient Roman!

Photo by Cunard White Star Ltd

Every ship has a salon or ballroom where, when night has fallen at sea, the passengers may gather to dance or to listen to the ship's orchestra, which is always made up of skilled musicians.

But as they went to bed that night they talked most of all about their wonderful visit to the bridge of the "Sanconia," where they had watched the helmsman guide the ship and had seen the marvelous compass by which he kept his course. There, in the chart room, they had also seen the many charts, or sea maps, which showed the depth of the water, what the bottom of the sea was like, where the various currents were, the prevailing winds, the location of lighthouses, channels, and buoys, and such other information as the helmsman needed to have. Of course any niece or nephew of a man like Uncle Tom was a pretty special sort of person!—Ted and Jane were aware of that when the officer let them put their hands on the big wheel for a minute. And he showed them the machinery that steers a big boat automatically except at times when the waves are very high.

The Thrills and Fun of a Sea Voyage

It would take a whole book to tell all that Ted and Jane did on this wonderful voyage, for Uncle Tom kept them busy every day from morning till night. As they made ready to land at the end of their six days' trip, they had far too much to remember. There had been a masquerade party the fourth night out, and a charity night when almost everybody took some part in the fun and helped to raise money for the disabled sailors in hospitals ashore. Then they had passed another great liner out on the sea, and had even sighted a huge iceberg slowly drifting down from the north. And the whales they had seen! And the schools of porpoises! And the life-saving drills!

What Makes Us Get Seasick

Jane said that she would never forget the stormy night when the billows heaved and the great ship pitched and lunged through the tossing sea. Uncle Tom said it was only a little squall, but Jane found it worse than that. Things had gone wrong underneath her sash somehow, and the billows were not doing all the heaving. It all ended in a trip to the ship's hospital, where the doctors and nurses took care of her. They even told her it was not her stomach that bothered her at all, but her ears! When you get seasick, it is the fluid in the little canals of the ear that makes all the trouble.

Ted Longs to Become a Sailor

Ted had been lucky enough to escape all that, and he was thinking most about all the fine officers he had met. After he had talked with the captain he felt sure that he would have to be a sailor when he grew up. Of course he was a little discouraged when Uncle Tom told him about all the hard work officers must do for many years before they reach their high rank, and of how they have to spend their whole lives at sea. But all the officers, the captain, the first officer and second officer, the chief surgeon, the purser, the chief engineer, and even the chief steward, looked so splendid in their trim uniforms, with gold stripes and other decorations, that Ted thought he would be willing to go through anything if he could only look like them and help to direct some great liner like the "Sanconia."

Tips, Tips, Tips!

Long before docking at their English port, Uncle Tom had given up their tickets to the purser, and had made sure that their passports, which had been properly visaed before they sailed, were tucked safely away in his bill folder ready to be shown to the authorities when the time came to land. Just before they left the ship he was busy handing out the usual tips to all the stewards who had been of service to his party. He took care to give the tips in English money, which he had secured at the purser's office.

When, finally, the "Sanconia" had docked alongside the pier at Southampton, and the gangway had been let down, Jane, Ted, and Uncle Tom handed an officer the landing tickets they had received at breakfast that morning, and started down the pier to the boat train that was to carry them to London. Ted and Jane told Uncle Tom that their trip across the wide Atlantic had been something beyond their rosiest dream.

Reading Unit No. 18

BOATS TO PLY BENEATH THE SEA

Note: For basic information not found on this page, consult the general Index, Vol. 15.

For statistical and current facts, consult the Richards Year Book Index.

Interesting Facts Explained

Why John P. Holland needed exactly $347.19, 10-307
Submarine invention in America and France, 10-308
The first submarine to sink a warship, 10-308
Why submarines cannot go very deep into the water, 10-309
How submarines can rise or submerge at will, 10-309
How officers see the world from the submarine periscope, 10-310
The dragons of the World Wars, 10-310

Things to Think About

Why does a submarine not dare to go more than a few hundred feet below the surface?
How is a submarine made so that it can submerge rapidly?
How does a submarine get its electric power?
How does a periscope work?
Why is it an advantage for submarines to go deep?
How is the submarine used in wartime?

Picture Hunt

What is the principle on which the periscope works? 10-306
What does a submarine look like when it is stripped for action? 10-307

Related Material

What makes things sink or float in water? 14-535, 1-467-74
Why is it dangerous to work in compressed air? 1-461-62
How do salmon travel up a river? 3-245-46
What does a storage battery consist of? 1-498
How did Daimler's internal-combustion engine work? 10-278

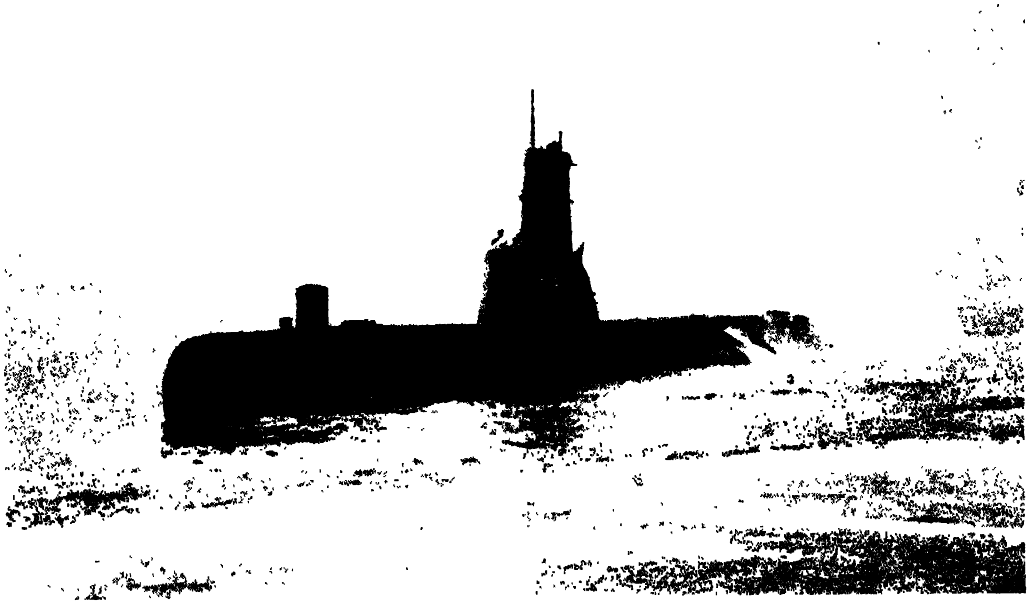
Leisure-time Activities

PROJECT NO. 1: Make a periscope, 10-306
PROJECT NO. 2: With a toy boat and a piece of lead, work out an experiment to show how the lead will sink and how it can be made to float, 1-470

Summary Statement

Although submarines have been used only to blow men and women into eternity, Simon Lake, when trying to invent them, thought they might be used for dredging the ocean floor, for navigating ice-bound harbors, and for recovering sunken treasure.

After taking a long, careful look at these pictures you will find it easy to understand how a periscope works. You may even make a simple one out of a couple of mirrors and a piece of old stovepipe. In the big picture we have a glimpse of the inside of a submarine, and can see how the periscope tube, with its little mirrors at the top, thrusts up through the water. The mirrors catch the view all around the horizon and reflect it to the mirror below. There it makes a picture that faithfully represents what is to be seen above. The little picture at the right shows how simple the principle is. That youngster on top had better look out!



Official Department of Defense Photo

This is the USS "Pickerel," a 1,850-ton "guppy snorkel" submarine, famous for its long under-water trip in 1950. It went down off the coast at Hongkong and came up 505 hours later- over 21 days near the entrance to Pearl Harbor, having traveled a distance of 5,200 miles. It was a record, and the trip made headlines around the world. The "Pickerel" owes this record to its snorkel, or breathing tubes, that supplied air.

BOATS *to* PLY BENEATH *the* SEA

The Submarine, First Built over Three Hundred Years Ago, Can Travel either above the Water or beneath It

"AND I need exactly $347.19. If only I could get hold of that much!"

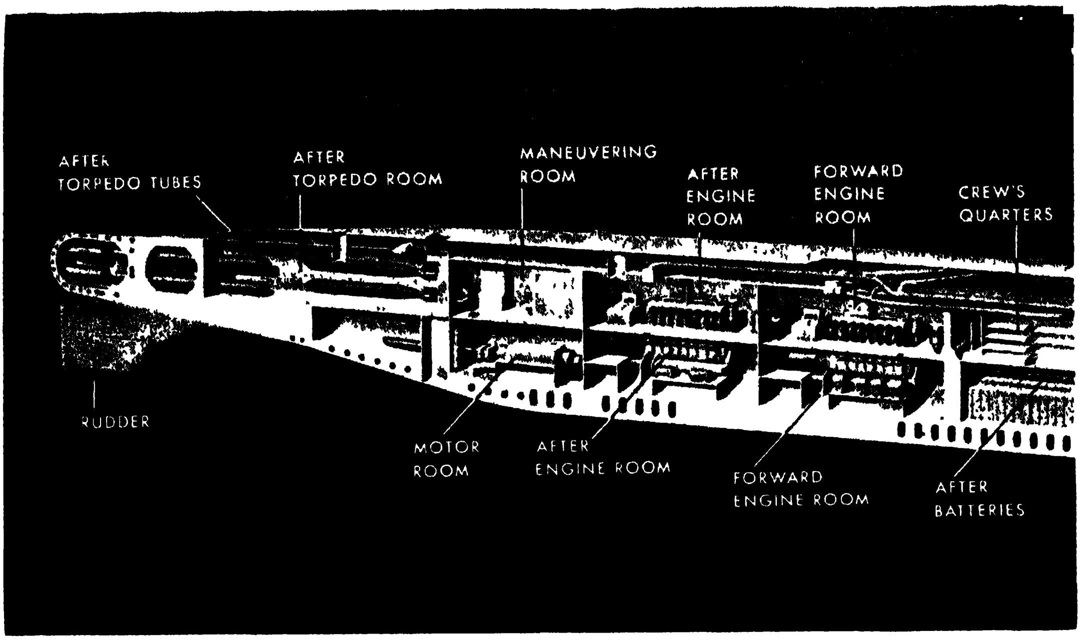
It was in 1893, in a restaurant in New York, and the speaker was John P. Holland. Not so many years before, he had been a school teacher in Ireland. But his head was full of the idea of making submarine boats. He had come to America with the plans that the people in his native city of Cork only found absurd. For twenty years or so he had been making one submarine after another, and learning a little from every failure, no matter how hard people laughed. But he had gone through every cent he had, as well as all that he could borrow. And now the government in Washington was inviting plans for a submarine for the Navy, and he did not even have enough to draw the plans. He was telling it all to a young friend.

"That's an odd figure," said the friend; "what is the nineteen cents for?"

"Why, for the ruler I must have to draw the plans."

The friend was impressed by the close estimate, and found the money for the inventor. In exchange he took stock in the Holland Torpedo Boat Company. And in due time he became a millionaire; for Holland's plan won in the competition, and he secured orders in America and from other lands. The Holland No. 9, put in commission by the United States in 1900, may be said to have been the first of the modern submarines.

Not but that there had been submarines before. As far back as 1620 a Dutchman



Drawing by James Cutter

This is the guppy submarine, named after a streamlined little tropical fish. Its smooth surface is broken only by the conning tower, which houses the periscope, the radar equipment, and the snorkel. Since this boat is under water most of the time her deck guns have been removed, and new electric torpedoes have been

named Van Drebbel built three under-water boats for King James I of England. Each was a big wooden vessel with a water-tight deck covered with thick, well-greased leather. Twelve rowers propelled the boat at a depth of twelve feet, and they could stay under water for several hours. But how Van Drebbel kept them from suffocation we cannot guess. If he had found out the secret of compressed air so long ago, he took it with him to his grave.

The First American Submarine

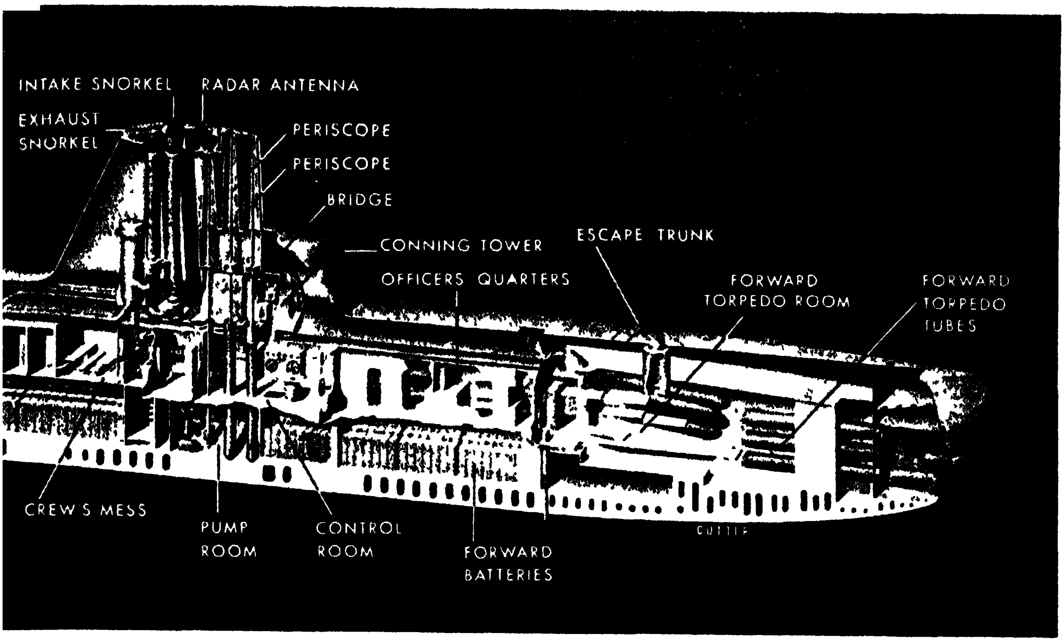
Then in the American Revolution a Yale student named David Bushnell made a submarine out of heavy oak, and Sergeant Lee ventured out into the harbor of New York in it. He got under a British ship and tried to blow it up. But he could not manage to attach his explosive to the copper bottom of the ship. Later, Robert Fulton tried to interest Napoleon in a submarine that could stay under water for four hours and carry a torpedo. If Napoleon had had faith in it, the Battle of Trafalgar might possibly have had a different end.

In the American Civil War the Union vessel "Housatonic" was blown up at Charleston by a Confederate submarine named the "Hundley" though she was often called the "David" because she seemed such a little craft to go forth against the giants of the sea. She went down with the boat that she destroyed. She was the first submarine to sink a warship and the last to do so until the First World War.

The First Successful Submarine

In the meanwhile came Holland, and a number of other men working at the invention in America and France. Among the others, Simon P. Lake is the most noteworthy. He was the rival of Holland, and his submarines were fitted with wheels for use at need in traveling on the floor of the sea.

The first Holland submarines were only about fifty feet long, and weighed only about two hundred tons. But in World War II the Japanese had submarines weighing as much as 4,600 tons and Midgets carrying only two men. Those in our own Navy weighed between 1,525 and 1,570 tons. A submarine's strength and speed do not depend



installed, which fire silently at targets located by instruments. To ballast the narrow, high ship many more powerful storage batteries have been added, which will drive the guppy 8 knots faster than older boats. Thanks to the snorkel the guppy's crew remains comfortable under water for weeks at a time.

on its size The submarine is just a boat that can travel either on the surface of the water or beneath it But in order to do that it has to be a very peculiar kind of boat. It is therefore very complicated, and there are also many kinds, though the main features of them all can be explained fairly easily.

First of all, it must be stoutly built for its special purpose of staying under water, where it has to stand all the pressure, or weight, of the water over it To that end it may have a single hull of steel, or a double one, and if a double one, many of the tanks and supplies are stored in the space between the hulls. The depth to which submarines can go is determined by the pressure. By changing the design of the hull the diving depth has been increased from four hundred to one thousand feet.

In order to rise or submerge, it has a number of tanks which can be filled either with water or with air. When these are full of air, it rides the waves, and when the water is let in, it sinks beneath them. If it wants to rise again, it forces the water out of the tanks with compressed air or electric pumps.

Now that is not so simple as it sounds. If you just add weight to something floating on the water, it may sink in any sort of queer position, or may roll over and over as it goes down. But the submarine must keep right side up as it submerges. It directs its nose downward when it dives, and its position is controlled by various carefully placed tanks, which fill with water. In addition the ship has a number of "fins" called "hydroplanes" which work at different angles and keep it straight under water.

Yet if you make a thing heavy enough to sink, it will keep right on sinking till it gets to the bottom of the ocean. That would never do for a boat. So the submarine must be made just heavy enough to go to a given depth and stay there *with the help* of its engines to keep it there and direct its course. All of this it can do very quickly. Some submarines submerge at the rate of forty-five feet in thirty seconds.

The amount of water added to make the ship submerge depends on the condition of the ship. When she has just left her base, she is very full of fuel and supplies, and so very heavy. When she has been out on a long cruise, she will be a great deal lighter.

The amount of water needed to submerge her will vary accordingly.

On the surface she is managed about like any other ship. Underneath she is operated from within. There is an instrument to show how level she is, and another to tell how deep she is. Above all, on every submarine there are two periscopes, through which her officers look out at the world above. The periscope (pĕr'ĭ-skōp) is simply a long steel tube, with the top sticking out above the water. It is fitted with lenses that will show the men down below what is going on above. It may be some thirty feet or more tall, which means that the men can see from that far down below. Above the water it is only about three inches thick, and is therefore very hard to see from any distance. It will show whether there is any hostile ship or airplane about, and will allow the officer below to steer in the right direction.

What Is a Snorkel?

The older submarines are driven by electricity under water and by steam or oil on the surface. And the electricity can be ade only on the surface. But the invention of an extensible double tube called a snorkel makes it possible to use Diesel engines when the craft is cruising at periscope depth. This gives much greater power and makes it possible to stay under indefinitely. A valve keeps water out of the snorkel. Every square inch aboard is used for machinery and supplies, but submariners say there is room for everything except a mistake.

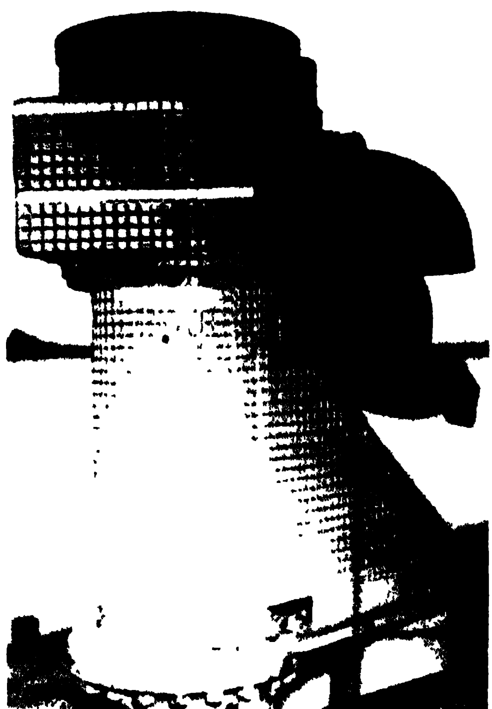
Finally, since the submarine is a war vessel, she must be equipped to fight. But she does not brave a cruiser on the surface. Her chief weapon is the torpedo, fired by compressed air through the water and using the periscope to take aim. One of these torpedoes can sink the proudest ship.

In addition, a submarine is sometimes used in war for laying mines, transporting sol diers, oil, amphibious landing craft, and supplies– as at Bataan. It can serve as a radar picket to give warning and to control defense craft. It can fight other submarines and can launch guided missiles. It can even hurl atomic bombs at coastal cities. It can cross oceans without surfacing and stay out for over a year. But its chief purpose will still be the sinking of surface ships. And since it no longer needs to come to the surface for air, it is now very hard to detect.

A Deadly Weapon

In World War I the German submarines did terrible damage to the shipping of the Allies. They sank more than five thousand ships over eleven millions tons and threatened England with starvation. In World War II they were an even greater threat until the invention of radar (rā'där), which reported their position when they were surfaced. This made it possible for planes to destroy them with depth bombs.

When Simon Lake was trying to invent submarines he thought they might be used for dredging the ocean floor, for navigating ice-bound harbors, and for recovering sunken treasure. But so far they have been of hardly any peaceful use.



Official Department of Defense Photo

This close-up of a German snorkel on a Nazi U-boat was taken during World War II. The snorkel was developed by the Dutch and used by the Germans, but there have been many improvements since.

TRANSPORTATION

Reading Unit
No. 19

THE WINGS OF THE WORLD

Note: For basic information not found on this page, consult the general Index, Vol. 15.

For statistical and current facts, consult the Richards Year Book Index.

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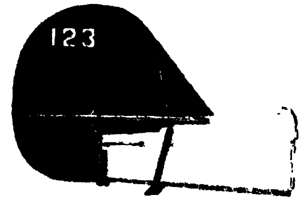
Leisure-time Activities

PROJECT NO. 1: Make a model airplane.

PROJECT NO. 2: Pay a visit to an airport.

Summary Statement

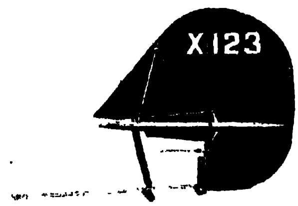
The airplane is the last word in travel and in transportation, for with it we can fly faster than the birds and can travel almost anywhere. It is changing our whole idea of geography.



WHAT THE MARKINGS MEAN

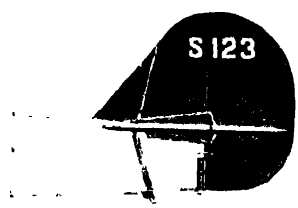
This page will tell you what airplane markings mean. In the United States numbers are assigned by the Department of Commerce.

Numbers with no letter prefixed belong to registered but unlicensed or temporarily licensed planes.
An X prefixed shows a plane to be an experimental model, not yet federally approved. It cannot charge a fare.

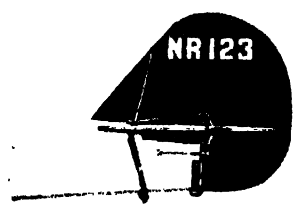


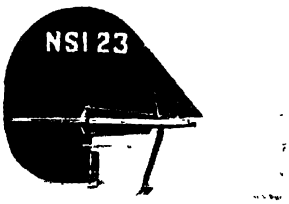
E, H, or K following the numbers are serial letters used only to shorten the length of the numbers.
An R means that a plane is licensed only for certain purposes. Only the crew and the pilot may ride in it.

C means that a plane has been licensed to fly commercially in the United States, and may be hired.
A plane licensed and operated solely by the government or state is marked S. It may not charge a fare.

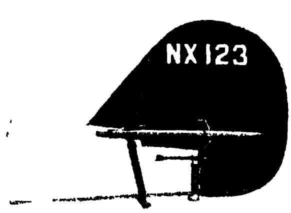


NC indicates an airplane licensed for international flying, such as the carrying of mail.
A plane marked NR may fly outside the United States, but is restricted in its use.

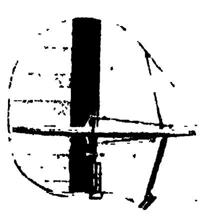


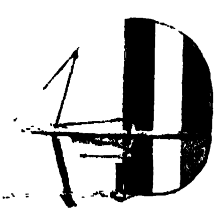


NS means that a plane is licensed and operated solely by the government or state but may fly internationally.
An experimental model that may fly internationally though it has not been federally approved is marked NX.



In peace time United States Army planes had red, white, and blue stripes on the rudder, and a star within a circle.





In peace time United States Navy planes bore red, white, and blue bars on the rudder, and a star within a circle.

Photos by S. O. Co. of Ohio

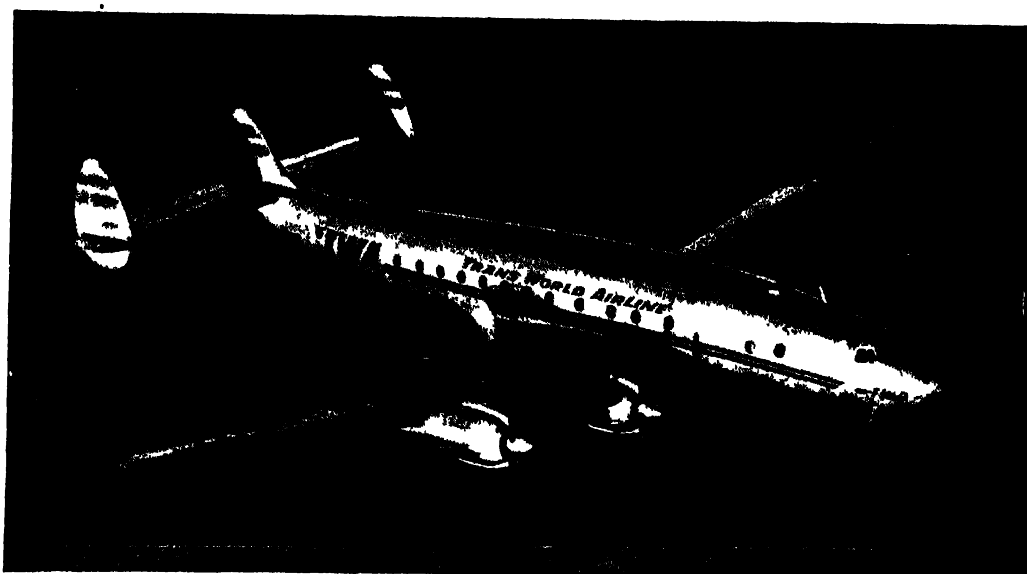


Photo by Lockheed Aircraft Corporation

This Pullman of the skies will carry you over land and sea as easily as the magic carpet did in the famous Arabian tale. And it will give you a great many more comforts! Traveling in the smooth, clear air of the substratosphere at 300 miles an hour, you will be free of shocks and jars. The luxurious cabin is air-conditioned and pressurized for comfortable flight at 20,000 feet. Any two of the four giant engines can carry the plane with safety to its destination, and a hydraulic-booster control system gives the pilot as delicate control of his craft as a woman has at a sewing machine.

The WINGS *of the* WORLD

For Many a Century We Dreamed of Flying Like a Bird, but Only a Few Years Ago We Found Out How to Do It; and Now We Can Fly All around the World

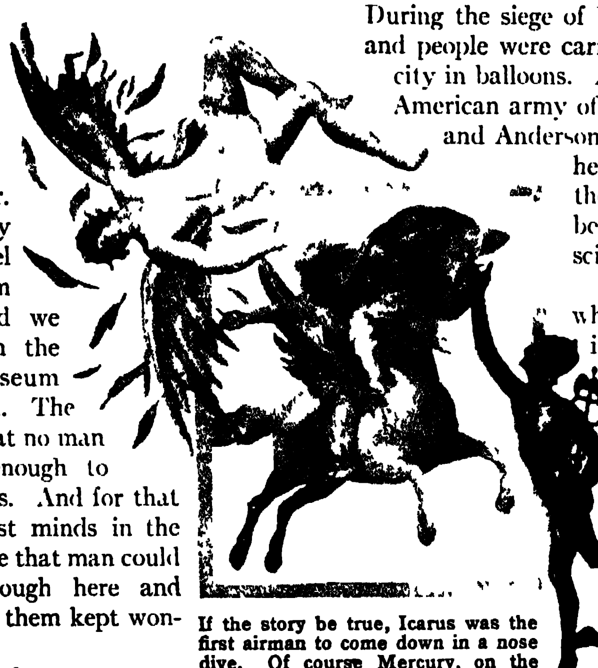
IT WAS cold and windy on Kill Devil Hill. Some of the little knot of men gathered there on a December morning in 1903 must have felt foolish for coming out. One of them, however, may have thought it was worth his while to be there. That was the village undertaker, who may have been pretty certain that there would be work for him before the morning was over. For on this day the two brothers who had been practicing on the sand dunes of Kitty Hawk, in North Carolina, were going to try to show that they could fly.

There they stood beside their curious machine with two big planes like a huge and awkward kite—Wilbur and Orville Wright, ready to prove their faith in their invention. Orville took his seat at the controls in the cockpit between the two planes. Wilbur started the six-bladed propeller whirling in front The engine began to hum. Slowly, while the watchers held their breath, the machine picked up its speed and rose into the air. It stayed up for twelve whole seconds! And that day it made three more flights, rising even to eight hundred feet and flying for fifty-nine seconds—all but a minute!

On that day an old, old dream of man came true. Man could fly. Long ago he must have dreamed that he was flying, as he lay asleep in his cave, just as many of us dream it in our beds to-day. Later on, he made up the story of Hermes (hûr′mēz), the messenger of the gods, who could speed through the air like a bird. And he had still other flying stories—of Bellerophon (bĕ-lĕr′-ŏ-fŏn), who mounted the winged horse Pegasus (pĕg′ȧ-sŭs) and slew a frightful monster; of Icarus (ĭk′ȧ-rŭs), who stuck

wings on his shoulders with wax and flew very well until he came too near the sun—when the wax melted and he fell headlong into the sea.

These were only stories. But centuries ago a few men of genius were also wondering how they could really do what a bird does. Just before Columbus found America, the great Leonardo da Vinci (dä vēn'chē) drew the plans for a wing-flapping machine in which he thought a man might soar in the air. In our own day a little model was built from his plans, and we may see it in the National Museum at Washington. The trouble was that no man had muscle enough to work the wings. And for that reason the best minds in the world were sure that man could never fly—though here and there a few of them kept wondering.



If the story be true, Icarus was the first airman to come down in a nose dive. Of course Mercury, on the right, never had any trouble in aërial navigation, for he was a god and so did not have to observe the rules of the game. And all Bellerophon needed to do was to give his mount the reins and Pegasus, like any other good steed, would bring his master home.

They did find out a way, to be sure, of rising in the air—but only in a machine lighter than the air itself. About 1782 two French brothers named Montgolfier (mōN'gôl'fyā') began wondering what kept the clouds up in the air; and being paper manufacturers, they thought a paper bag might also rise in the air if it was filled with something like a cloud. They made a little fire under the bag, and the bag rose and soared. The brothers thought it was the smoke that did the work, and did not know it was the thin air in the bag—thin because it was heated. All the same, they kept on working until they had a sizable balloon, with a straw fire under it, that went up pretty high and traveled for a mile or so before it came down.

Then it was not long before balloons were lifting people up into the air—at first with sponges to put out the fire if it grew dangerous. Soon the fire was given up, however, and the balloon was filled with hydrogen (hī'drô-jĕn) gas, which is much lighter than the air. By 1785 two men had crossed the English Channel in a balloon. And soon after that balloons had become very common. They have been so ever since—for fun, for war, and for scientific observations. During the siege of Paris in 1870, messages and people were carried out of the helpless city in balloons. And as late as 1935 two American army officers, Captains Stevens and Anderson, rose in a balloon to a height of 13.7 miles—the highest man had ever been to gain valuable scientific information.

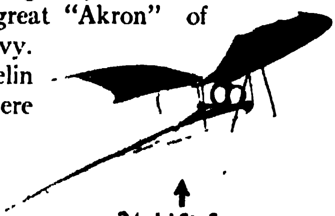
A balloon can go only where the wind will take it. At the very first a few attempts were made at guiding it - even with things like oars to row it in the air. But little could be done to make it go where we desired until we had very modern engines.

About the time when the Wright brothers were working at an airplane in their bicycle shop at Dayton, Ohio, a dashing young Brazilian named Santos-Dumont was delighting Paris with his flights in a cigar-shaped balloon with a propeller in front and a rudder in the rear. He had put a gasoline engine in the balloon, and in 1904 he won a prize of $20,000 for circling the Eiffel Tower in a stiff breeze and returning to his base.

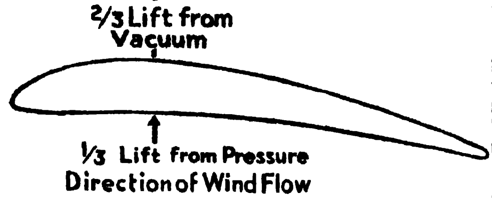
The First Airship

In the same year Count Zeppelin of Germany brought his Zeppelin No. 1 out of her shed on Lake Constance. She was a huge affair—the parent of all other Zeppelins down to the one that crossed from Germany to America in less than five days and later

sailed around the world in 1930. For owing mainly to Count Zeppelin's efforts, we now have immense dirigibles (dĭr'ĭ-jĭb'l)—balloons that can be steered wherever we desire—capable of going anywhere. Such an airship was the great "Akron" of the United States Navy.



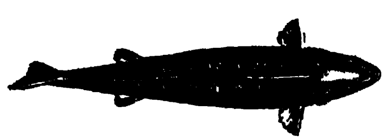
Here at the left is the little mosquito-like glider that Leonardo da Vinci planned four hundred years ago.



The diagram above will show you why an airplane flies. The principle is very simple. The airplane wings are tilted upward a little, so that as the propeller drags the machine rapidly forward through the air, the wind hits the under side of the wings with such force as to push the plane up. It is just what would happen if you blew up at a sheet of tissue paper floating above your head. But science has learned how to help the wind lift the plane. It does this by curving the upper surface of the wing—as you see above. The air, upon hitting this curved surface, shoots straight up. The rapidly rising current tends to create a vacuum just above the wing—or, in simpler terms, as the current rises it sucks the wing up with it. This suction is really twice as powerful in raising a plane as the push of the current of air on the under side of the wings.

Of course a Zeppelin is anything but a mere balloon. It has a vast and intricate metal framework. Around this is an outer skin, held rigid and by no means collapsible like the old-time balloon. Inside are rubber-coated bags filled with light gas. This used always to be hydrogen gas, which will explode if it touches fire—as it did in the ill fated British airship R-101, which blew up and brought death to all on board. Now we use helium (hē'lĭ-ŭm) gas whenever possible, because it will not burn. The world's richest supply is in America.

Now all these mighty machines are lighter than the air. They simply float. There is no trouble in making them rise, and we have conquered all the troubles of keeping them steady, even in a storm, and making them go where we want them.



Photos by S. O Co of N. Y.

One reason why a fish can dart about with such ease is that he is so shaped as to offer the least possible resistance to the water. Nothing on him sticks out except the fins that row him along. The airplane has borrowed his plan of construction in this matter. Everything that could catch the wind, even to wires, is "stream-lined"; that is, the parts are all so shaped that the wind will flow past them as easily as possible.

But an airplane is heavier than the air. It has no gas to make it float. So now let us come back to the Wright brothers and find out what made their plane go up in the air and stay there.

Did you ever throw a thin, flat stone straight out on a level line in front of you? What happened to it? Why, the stone did not go level at all. Instead, it rose right up into the air until it had nearly spent its force. Then it fell to the ground. Now the stone is a good deal heavier than air, and yet you have seen it mount the air so often that you probably have never even wondered why it does so. But if you have ever found out why it rises and then falls, you know all the secret of the airplane.

The air has a certain weight, and therefore a certain resistance. If a thing is tearing through it very fast, there will be a great deal of resistance—as you may have felt if you ever put your hand out of a car window. But the stone is going a good deal faster than a car, and meets a good deal more resistance; so if the stone is flat and tilted upward a little bit, the resistance of the air will make it climb. It will keep climbing as long as it is going fast enough. When it slows up, there will be less resistance, and it falls. That is all.

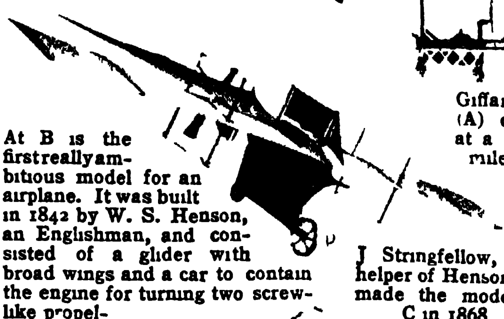
And that is all that makes an airplane rise. It is a flat thing too. And it can be tilted up, or at least parts of it can. And then if it has an engine to send it through the air fast enough, it will rise and fly. It can keep flying as long as it goes fast enough. But if the engine fails and it slows up or stops, it will fall—like the flat stone.

Like so many other great inventions the airplane is the result of the work of many different men in many different countries, each one contributing his own little bit. Some of the early machines are shown on this page

Men had to experiment with balloons and gliders for a long time before it was possible to try driving them with an engine. But in 1852 a Frenchman named Henri Giffard made a flight in an airship (A) propelled by a very light steam engine

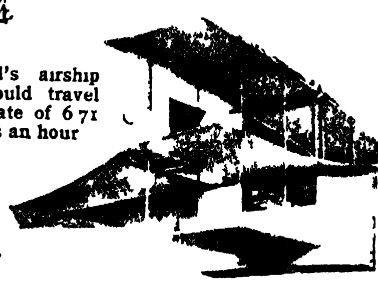
Giffard's airship (A) could travel at a rate of 6.71 miles an hour

At B is the first really ambitious model for an airplane. It was built in 1842 by W. S. Henson, an Englishman, and consisted of a glider with broad wings and a car to contain the engine for turning two screw-like propellers



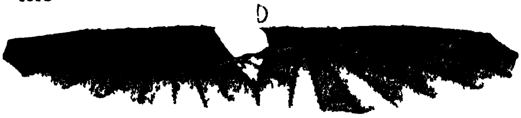
J Stringfellow, a helper of Henson, made the model C in 1868

Stringfellow's model C had three tiers of wings and an engine to turn the screws

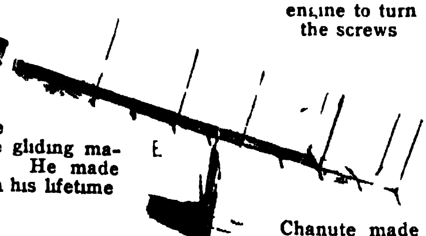


Lilienthal in Germany built this bat-like glider D in 1895. He proved that arched wings were better than flat ones

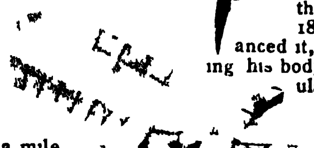
Lilienthal was the first man to make gliding machines practicable. He made over 2,000 glides in his lifetime



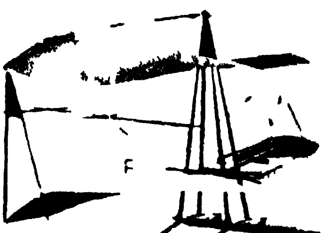
Chanute made the glider E in 1896. He balanced it, not by swaying his body, but by regulating the wings



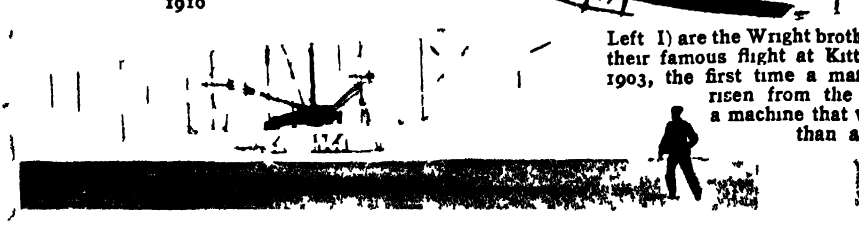
At G is Samuel Langley's ill fated machine which was twice wrecked in the launching in 1903. One he built in 1896 flew half a mile but it was not intended to carry passengers



At F is another glider, made in America by Gallaudet in 1898



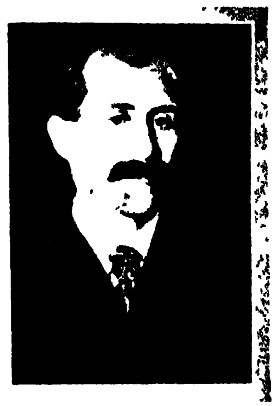
At H is Glenn Curtiss's hydroplane, the "Junebug," as it was piloted up the Hudson by its inventor in 1910



Left I) are the Wright brothers making their famous flight at Kitty Hawk in 1903, the first time a man had ever risen from the ground in a machine that was heavier than air.

Now let us go back to the stone a moment, or better, let us take a piece of tin or cardboard. When we throw this through the air it does far more than rise—it often flops around and turns over and over. And of course that would not do for an airplane. The airplane must not only rise when we like, but it must then stay level and steady, turning only when we like, and going where we want it. So it must have things like fins and rudders to keep it straight upon its path.

Those were the things the Wright brothers had to learn to do. They had to find an engine that would drive a plane fast enough, and all sorts of contrivances to keep it steady enough. It is easy to say this, though it was hard enough to do it. Anybody who has ever flown a kite will know a little about how hard it is to keep a thing steady in the air—to say nothing of a storm. But once the Wrights had found a way to do all these things, they could fly.



Photos by National Museum

In the oval is a picture of Professor Samuel Pierpont Langley, the distinguished American scientist who came so near being the first to build a machine in which a man could fly. The two other photographs are of Orville and Wilbur Wright, the builders of the first airplane and the first men to fly it.

Of course the Wrights learned a good deal from the men who had tried the same sort of thing before. They knew about the German Lilienthal, who had made many flights in gliders - planes without an engine- -before he was finally killed in one in 1896. They knew about the glider flights of the American, Octave Chanute (shà-nōōt′), who was just giving up in despair.

And they knew about the deeds of Samuel Pierpont Langley, the noted scientist of Washington. Langley had actually put an engine into his airplane. It was a fifteen-foot plane, and the engine, though very light, ran with steam. In 1896 it flew over the Potomac for a minute and a half—or as long as its fuel and water lasted. Seven years later Langley had a plane made to carry a man; but at its trial something went wrong with the launching gear, and it plunged straight into the Potomac. "My life's work is a failure," said Langley, who was now an old man, and had spent all the money that the government had allowed him. Just nine days later came the triumph of the Wrights.

The First Airplane to Fly

The Wrights had begun with gliders and worked up to planes with engines. For the gliders they had to be sure of steady winds, and they asked the Weather Bureau where to find them. The Bureau sent them to Kitty Hawk, in North Carolina. By this time the gasoline engine for automobiles had been developed, but it was still too heavy for the airplane. So the Wright brothers had to make their own engine. Their whole machine, with a man in it, weighed only eight hundred pounds.

Now if you will look at the pictures, you will see most of the things that were invented to make the airplane rise and to keep it steady. There is the powerful engine to do the driving; it turns the propeller which whirls through the air at a dizzy speed and pulls the plane after it, just as a propeller in the water pushes a boat in front of it. There are the great wings—single in a monoplane, double in a biplane—which make it rise and sail when it is driven fast against the air. There is the tail plane, to keep the whole machine going steadily; with a rudder to steer it in the right direction and an elevator to tilt it up or down according as we want to rise or descend. There are the ailerons (ā′lĕ-rŏn), or "little wings," which can also

Photo by Soibelman Syndicate

This remarkable photograph shows the disaster that overtook the giant zeppelin "Hindenburg" at Lakehurst, New Jersey, in 1937. Just as the dirigible was coming to her moorings after one of her regular passenger flights across the Atlantic, the stern burst into flames and with a terrific report the airship fell to the ground, a mass of fire. She had 107 persons on board, of whom 36 were killed. It was thought that a form of electricity known as St. Elmo's fire may have ignited the hydrogen gas with which the ship was inflated. The "Hindenburg" was built in Germany, and had been in service for over a year. She was 803 feet long and 146 feet high, had a cruising speed of 78 miles an hour, and carried 72 passengers.

be tilted up or down to keep the whole thing steady. And there is the cockpit, in the front part of the fuselage (fū'zĕ-lâj), where the pilot sits and controls all of these and other parts of the plane. Finally, there is the chassis (shȧ'sē), with wheels for starting over the ground and for landing on it.

Wings of the World War

All of these things have been greatly developed and perfected since the day when the Wrights first made them succeed. Almost from that very day, things began to go rapidly. The inventors gave a demonstration for the government, which bought a model in 1908—the first airplane that any government ever owned. They went to fly in Europe, where the French especially seized on their idea and began to improve it. By 1909 Bleriot (blĕ'rē'ō') had flown across the English Channel. The next year Glenn Curtiss, inventor of the hydroplane, flew from New York to Albany in two hours and forty-six minutes. Every few days a new marvel came in aviation.

Then came World War I, with an immense development in flying. At once it was seen how important aircraft would be in flying over the enemy's country and getting all sorts of information, as well as in attacking towns and troops, and later submarines. Dozens of new types of airplanes were perfected and thousands of men were trained to fly and to fight in the air. People got used to the idea of flight, and after the war the building of planes and the establishment of air lines became a great industry. To-day we can travel almost anywhere by air.

Just one hundred years after the little "Savannah" had set out to cross the ocean

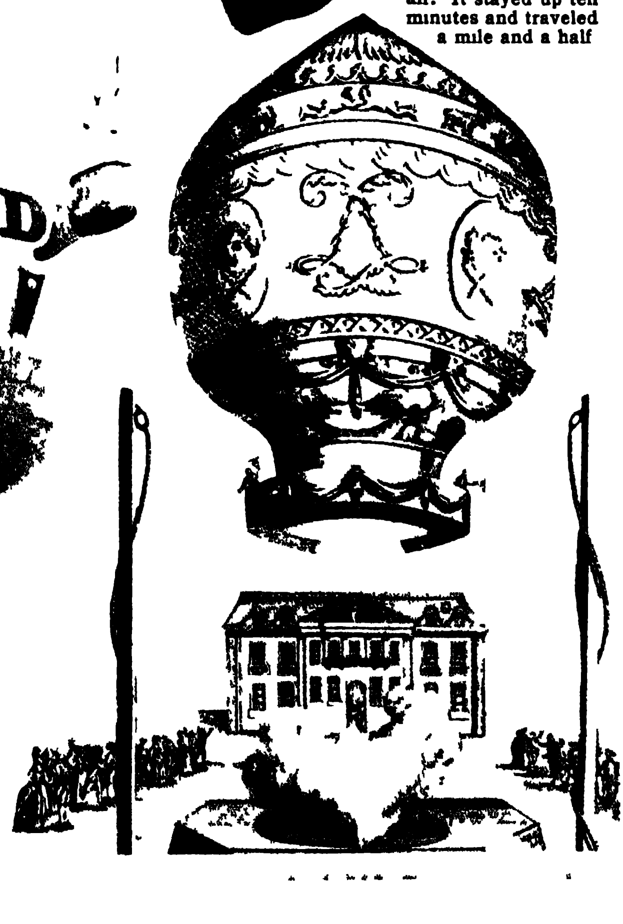
Before a zeppelin could be built men had to learn how to make balloons. The first of these was a toy that Joseph Black, an English scientist, made in 1767 by filling an envelope with the newly discovered hydrogen gas

In 1783 a gas-filled balloon was sent up by Charles, a French scientist But when it came down the peasants took it for a dragon and tore it up

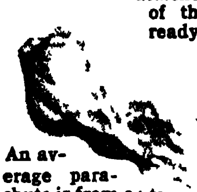
The affair above, which looks like some strange monster that Noah refused to take into the Ark, is an observation balloon belonging to the United States Navy

Below is the famous balloon of the brothers Montgolfier, the first that ever was sent up outdoors It was 105 feet in circumference, and was filled with hot air. It stayed up ten minutes and traveled a mile and a half

Above is the commonest type of balloon, a round gas-filled bag with a a basket suspended below it These were the affairs in which brave souls used to ascend for fifteen minutes at the county fairs The balloon was always anchored.

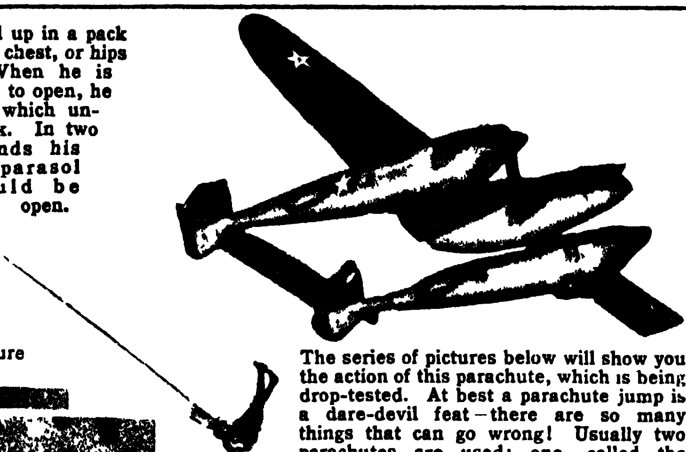


Photos by U S Navy and the Goodyear Co

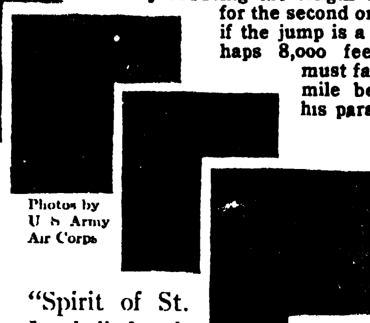


A parachute is folded up in a pack attached to the back, chest, or hips of the jumper. When he is ready for the 'chute to open, he pulls a cord which undoes the pack. In two seconds his big parasol should be open.

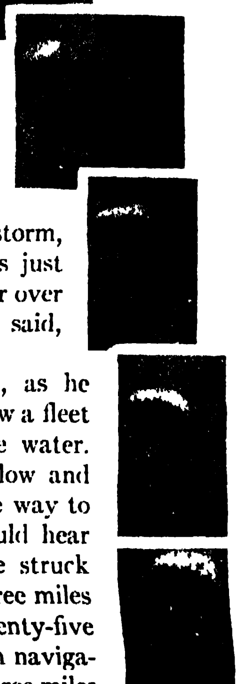
An average parachute is from 24 to 28 feet across, is made of silk, and weighs 18 pounds. Its jerk upon opening, after a man has already fallen half a mile, is terrific. It is sure to leave him black and blue. And the cold of that first free fall is almost paralyzing.



The series of pictures below will show you the action of this parachute, which is being drop-tested. At best a parachute jump is a dare-devil feat—there are so many things that can go wrong! Usually two parachutes are used; one, called the "pilot," is small and serves only to drag the big parachute out of its case, in this way reducing the length of time needed for the second one to open. But if the jump is a high one perhaps 8,000 feet the jumper must fall for some half mile before he opens his parachute. Arthur Starnes, jumping at 31,400 feet, dropped 29,000 feet before opening his parachute.



Photos by U S Army Air Corps



by steam, the first airplane was flying across the Atlantic. Lieutenant Commander A. C. Read, in the American Navy plane NC-4, flew from Newfoundland, by way of the Azores, to England. A month later the English officers, Alcock and Brown, made the first non-stop flight across the ocean. They went from Newfoundland to Ireland, a distance of 1960 miles, in sixteen hours and twelve minutes.

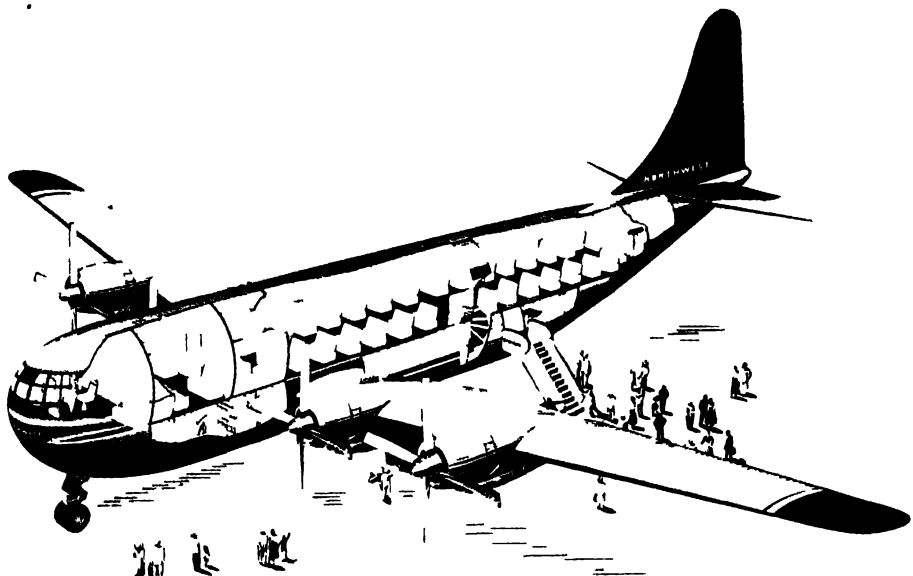
The Hero of the Air

After that, one record was broken after another. There was a flight from London to Australia—11,500 miles. There were flights all the way across America, and to Alaska, and from San Francisco to Honolulu. Richard Evelyn Byrd flew over the North Pole in an airplane, as Amundsen flew over it in a dirigible. In 1928 Wilkins made his remarkable flight of 2,100 miles through the Arctic wastes from Point Barrow in Alaska to Spitzbergen. There have been many other notable flights.

Most famous of them all was that of Charles Augustus Lindbergh from New York to Paris, in 1927. He was the eleventh man to cross, but the first to reach the exact spot he set out for. And he went alone. "So long!" he said, on the drizzly Friday morning when the weather man finally told him to go ahead. Then he shot off in his silvery "Spirit of St. Louis," heading for Newfoundland. There he met such a bad sleet storm that for a while he thought he might have to turn back. But he rose above the storm, and kept on. "It was just like driving a motor car over a smooth road," he said, "only it was easier."

The next afternoon, as he was nearing land, he saw a fleet of fishing boats in the water. He came down very low and called out, "Is this the way to Ireland?" But he could hear no answer. When he struck Ireland he was just three miles out of his path. "Twenty-five miles would have been navigation," he declared; "three miles was just luck."

But he was bound for Paris, and at ten



An airfield is an interesting place when one of the great "skyliners" is about to take off. The shining plane taxis into place, the door is opened and the gangway let down, and the passengers go quietly on board. There is almost no bustle, but the atmosphere is charged with excitement nevertheless, for everyone seems to realize that this is something the world has never seen before. When you have boarded your plane you will probably find that its inside plan is a good deal like the plan shown above.

o'clock that night he saw the glare of the lights at the great aviation field just outside the city. They showed a mass of a hundred thousand people waiting. For the first time the young pilot was afraid. How could he land without crashing into the crowd? But he managed it, though the police could not keep the crowd back. Then he had a reception that he called "the most dangerous thing on the trip." He found he was the most famous man in the world.

The World's First Air Line

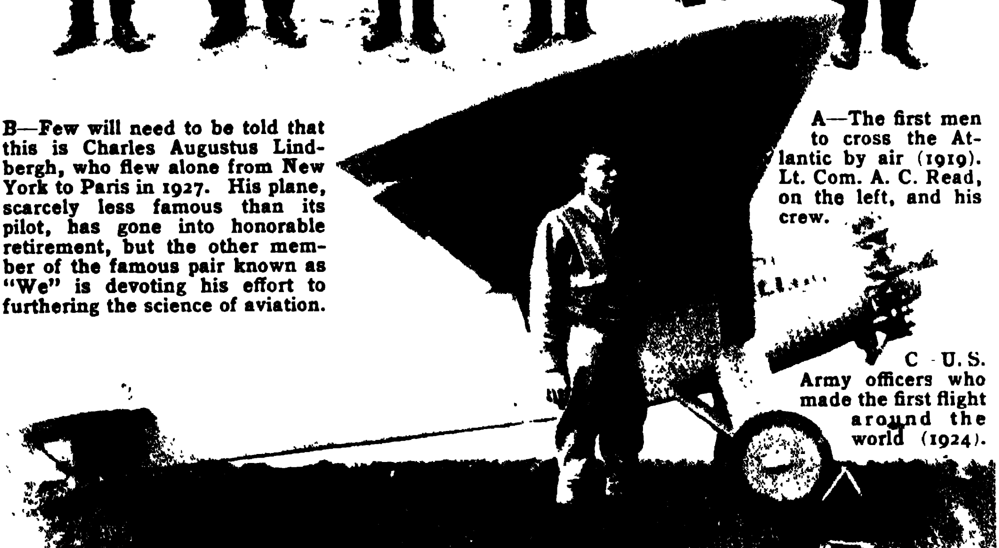
It was during the '30's that the airplane began to be at home in the skies. The world's first passenger service had been established in 1918, between Paris and London. In the same year the United States Post Office Department had set up the first air line in this country when it began to send mail by plane between New York and Washington. Little by little other mail routes followed. In 1926 the whole business of carrying air mail was turned over to private companies, which with the help they got in this way from the government were able to go ahead weaving the giant network of airways which now reaches into every corner of our land.

The Early Passenger Planes

At first they used bombers left over from World War I. Those rough-and-ready war planes gave no comforts to passengers, and not a great deal of safety. But people were eager to see what the bird sees, and slowly the business of flying grew. When the companies at last could afford better equipment and when the airplane industry had learned how to make planes that were both comfortable and safe, people began to flock to the air fields. For all along it had been mostly fear that had kept them on the ground.

In 1930 it was possible to go by air from Atlanta to Los Angeles on a regular schedule, though the trip had to be pieced out on various short lines. In the following year an uninterrupted route was established between New York and Los Angeles, but the trip took four days, since night flying was as yet unknown. That had to wait for beacons to be set up along the way. As various sections of the route were lighted, "Skysleepers" went

A—The first men to cross the Atlantic by air (1919). Lt. Com. A. C. Read, on the left, and his crew.



B—Few will need to be told that this is Charles Augustus Lindbergh, who flew alone from New York to Paris in 1927. His plane, scarcely less famous than its pilot, has gone into honorable retirement, but the other member of the famous pair known as "We" is devoting his effort to furthering the science of aviation.

C—U. S. Army officers who made the first flight around the world (1924).

Photos by Underwood & Underwood

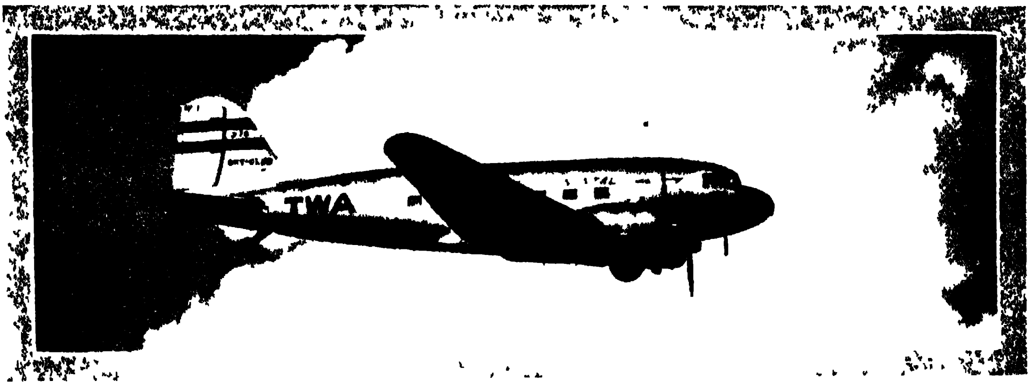


Photo by Transcontinental and Western Airlines

This transcontinental "airliner" is flying on even keel, but even if it were tilted very much to one side the passengers would have no knowledge of the fact unless they looked out of the window.

into service, the first appearing in 1936

With the establishment of the government's Civil Aeronautics Authority (1938) aviation came into its own It laid down all the rules that govern civilian flying except the designation of the mail routes. Strict regulations made air travel safe and protected companies and public alike No longer was a commercial air line financed by one of the various aircraft manufacturing companies, and so obliged to use the planes of the company that owned the stock. An air line now was like a railroad it was in the business of transportation only, and bought the best equipment it could find. By 1940 passenger planes, costing $100,000 apiece, had come to be as luxurious as a fine hotel The average flying speed had been increased from 120 to 190 miles an hour, and everything imaginable had been done to make the traveler comfortable.

How Air Travel Was Made Safe

But better yet, his fears had been put to rest. Every passenger plane was given at least two motors, so that if one engine stalled the other could still carry the plane to the nearest airfield, and emergency landing fields were laid out along all the air routes. Planes, too, were built with the utmost care. And an amazing system for guiding them in the air and bringing them safe to earth was doing away with crashes and landing accidents. To-day it is a good deal safer to take a commercial plane than it is to travel to one's destination by bus or by private automobile.

With their fears laid to rest, people began to travel by air not only because they were in a hurry but because it was fun Each year between 1935 and 1939 air travel in this country increased by nearly a fifth But in 1939 it increased by almost a half. And in the first six months of 1941 it had doubled the record of any year before 1939. By 1942 our commercial planes were flying 135,000,000 miles a year, along 29,000 miles of lighted airways, where no plane was ever out of sight of one of the 2,200 revolving beacons set up to help guide air traffic through the dark. Planes operating on regular schedule were carrying more than 4,000,000 passengers a year There was never an instant during the whole twenty-four hours of the day when there was not an average of 1,500 passengers and 18 tons of mail speeding through the clouds Three different lines were carrying people across the continent, one of them operating five flights in each direction every day It had come to seem quite natural that one should see the sun set in New York and watch it rise next morning in San Francisco. Altogether we had 44 domestic and 15 foreign airmail routes, and our planes at home were carrying over 14,000,000 pounds of mail a year over 39,000 miles of route.

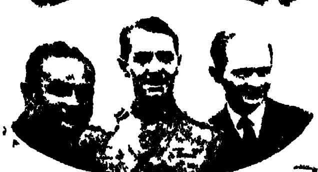
The Clippers and Their Routes

Moreover, the network of air lines had spread over all the oceans and to every land on earth, though there was more air travel

A — R. E. Byrd (left) and Floyd Bennett (right), the first men to fly across the North Pole (1926)

B When Louis Bleriot, the famous French airman, first flew across the English Channel in 1909 people thought it an interesting feat but nothing more. But only twenty years later, when this picture of him was taken after another similar flight, regular air services had been established between most of the world's important cities

C The "Norge," the Italian airship which flew across the North Pole (1926)



D The "Bremen," a German plane which made the first east to-west flight across the Atlantic 1928) Her passengers, from left to right, are Koehl, Fitzmaurice and von Huenefeld

E—Kingsford-Smith, captain of the crew that flew from California to Australia (1928). F—Coste, the French aviator, on his Paris-to-Texas flight. G—Maitland and Hegenberger, who made the first non-stop flight from California to Hawaii (1927)

Photos by Underwood & Underwood

in the United States than anywhere else. In 1920 we had set up a route between Key West and Havana. Later it was extended to all the countries of South America, binding together the business interests of the two continents. In 1933 the Germans had begun to fly ships from Africa to Brazil, stopping to refuel from a ship anchored in mid-Atlantic. Before long the giant "Clippers" were going across the Atlantic to England and across the Pacific to China and the Philippines. And eventually there was no important city in the world that could not be reached by air. The Pan American World Airways System, an American company maintaining lines to Central and South America, Europe, New Zealand, and the Orient, had, with its subsidiaries, over 30,000 miles of main routes.

Photo by Eastern Air Lines

All food except coffee is prepared before it goes on board an air liner, and as a rule comes from the kitchens of large hotels, where the menus are planned by trained dietitians. Here a chef at one of the lines' principal airports is superintending the loading of food into a plane that is about to depart.

The passenger who sits in luxurious ease in one of our great "skyliners" and watches village and city, mountain and plain roll silently by below has no notion of the unresting care that is keeping him safe in the air. First of all, there are the designers and builders. The best engineers in the world are at work on the giant airplanes that shuttle back and forth night and day, rain or shine. We have told elsewhere of all the amazing devices that make it possible for a plane to travel safely through the air and alight as gently as a piece of thistledown.

From 1936 on, the standard plane in use by all the air lines was the 12-ton Douglas—the DC-3. It carried twenty-one daylight passengers and a crew of three—the pilot, the first officer, and the stewardess. When built to serve as a "skysleeper," it had berths for fourteen passengers. Its pair of 1,100-horsepower engines gave it an average speed of 190 miles an hour. But that speed used only a little over half of the engines' full capacity. In other words, the motors were never overtaxed, and so, with proper inspection, never needed to break down. Those magnificent planes had a wing spread of 95 feet, were 16 feet, 11 inches high, and 64 feet, 6 inches long. Their cruising range was 1,700 miles.

In 1940 the famous "Stratoliners"—Boeing 307—went into regular transcontinental service, and marked another stride toward safety. For their four 1,100-horsepower motors could carry the 38-passenger plane at an altitude of 20,000 feet, well above most of the bad weather that is a common cause of disaster. Of course the Stratoliners did not actually reach the stratosphere (strā'tō-sfēr), that layer of calm thin air that begins some six or seven miles above the earth. But they did reach the substratosphere, and because the air is thin at that high altitude and offers much less resistance, they could cruise at 220 miles an hour and were very smooth in flight, since there were few strong currents of air to buffet them. Oxygen of course was added to the air inside the cabin. Stratoliners were built upon the same design as the Boeing bombers that we knew as Flying Fortresses in World War II.

A Powerful Passenger Plane

Just before the war began, the DC-4 ap-

peared, a new and larger Douglas. Boeing Clippers were two-deck trans-ocean flying boats carrying 82 persons. After the war Lockheed brought out the 64-passenger Constellation, which at 20,000 feet flies over 300 miles an hour. Its pressurized and air-conditioned cabin was insulated against noise and vibration.

In 1947 the DC 6 appeared. It has a wing span of 117½ feet and is 100 feet, 7 inches long. Four 2,100 horsepower engines give it a speed of 315 miles an hour at 20,000 feet. An ejector exhaust system uses exhaust gases from the engines to increase the forward thrust, as jets would. The plane carries 52 daytime passengers and a crew of 5, but will take 70 passengers on short trips.

Photo by American Airlines

The stewardess heats whatever food must be heated and makes the coffee. The meal is then served on trays to the various passengers at their seats. The stewardess above is about to deliver one of her trays.

All the time a plane is aloft, at least forty people on the ground are at work to keep it out of harm's way. To begin with, there are the weather experts in the "flight control stations" that are scattered at important points along the airways. They get hourly reports—called "weather sequences"—by teletype, giving exact details of weather conditions all along the route, and they report any news they may get of a change of weather.

Help from the Weather Bureau

Besides in addition to this careful system operated by each air line, government weather reports from hundreds of stations are constantly sent out to the air lines and relayed to the flight control offices. Every six hours the air line experts get weather map information and records of conditions in the upper air, and on the basis of all this knowledge they draw up a "route forecast" for each flying area. From the route forecast, "trip forecasts" are then made up, covering conditions at each stop, general flight conditions along the entire route, wind, and favorable flying levels.

Whenever a plane is to make a trip the crew must arrive at the airport an hour ahead of time. The captain and first officer examine the plane thoroughly and are given a "certificate of plane inspection," signed by the airfield's chief mechanic. It tells them that the plane has been put in condition by the airport's crew of highly trained technicians, men who have been carefully examined and licensed by the Civil Aeronautics Board. The two pilots also check the fuel supply and study the weather report and the "flight clearance." That "flight clearance authority" is a document issued by the airport's "flight superintendent," under whom the weather experts and the radio operators all work. No plane may leave the ground without this permit, which contains all the important information as to the trip, the plane and its load, and conditions along the line or to either side of it. Attached to the flight clearance are the reports of the government Weather Bureau and also the trip forecast.

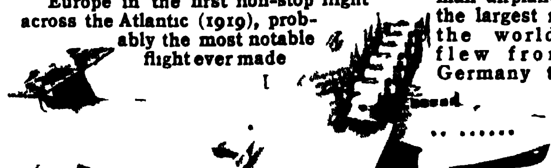
From all these facts the two officers and the station's chief weather expert now make out an elaborate document known as the "flight plan." It indicates the exact course the plane is to take, its altitude at every point along the route, the timing, and the plan of flight for each section, or "leg," of the trip. The altitude at which the plane is to fly will depend upon weather conditions, for in general it is the practice to leave clouds and storms below and mount up into the sunshine or starlight. For the sake of safety all

A—Amelia Earhart, the first woman to fly across the Atlantic, 1928 In 1932 she made a second flight alone

C

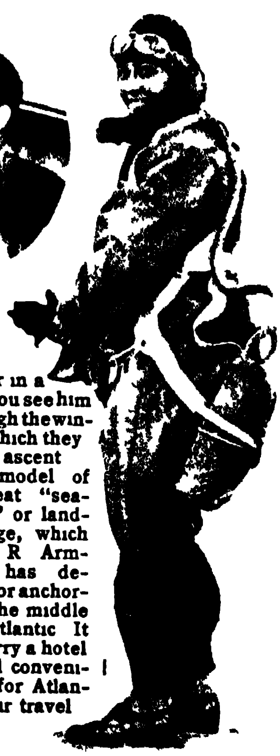
Harold Gatty (E) and Wiley Post (F) circled the globe in an airplane in 8 days, 16 hours (1931) Their route lay from Long Island to England, thence to Russia, Siberia, Alaska, and then home

Captain John Alcock (C) and Lieut Arthur Whitten Brown (B), the two Englishmen who flew from Canada to Europe in the first non-stop flight across the Atlantic (1919), probably the most notable flight ever made

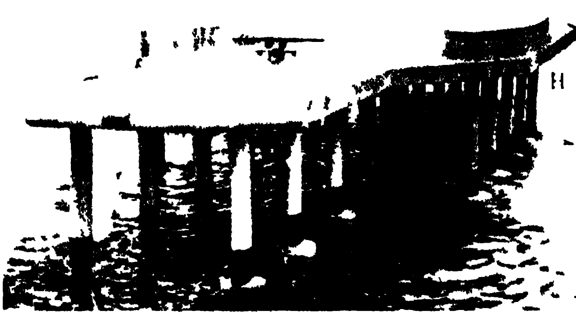


D The Do X, famous German airplane, the largest in the world, flew from Germany to South America in 1931

I Amy Johnson, a famous English aviatrix, who flew from England to Australia (1931).



G—Professor Piccard (right), who in 1931 climbed ten miles into the air in a balloon Here you see him and his assistant through the window of the metal globe in which they made the ascent



H—A model of the great "seadrome," or landing stage, which Mr E R Armstrong has designed for anchorage in the middle of the Atlantic It will carry a hotel and all conveniences for Atlantic air travel

Photos by Underwood & Underwood

Photo by Braniff Airways, Inc.

This might almost be the interior of a Pullman coach. The stewardess on the air liner is serving the passengers their meals. She will take especial pains to see that the baby's food is properly prepared.

west and southbound planes fly at even thousand-foot altitudes, and east and northbound planes at odd thousand-foot altitudes.

This flight plan must receive the approval of the flight superintendent, who is given a copy of it. Information as to its contents is then sent by wire or radio to airports along the way. No pilot may change his altitude in the course of the flight without first communicating with the flight control office and getting permission. If conditions look unfavorable for safe flight the plane will not be given its flight clearance.

With all plans carefully laid, the plane is now brought out on the runway and loaded with baggage and supplies. Through a loud speaker the departure is announced, just as a train departure would be announced in a large railway station. Each passenger's baggage has already been weighed, for the line will not carry more than 40 pounds per person without charge. The passengers too have been weighed, for the pilot must know the exact size of his load. If it is night, giant searchlights have been trained upon the runway till it is almost as light as day. Often a good many planes are landing or taking off, and the airfield is full of motion and excitement.

Finally, with passengers, mail, baggage, and supplies carefully stowed away, the gangway is drawn up, the plane's great door is locked, and the pilot awaits the signal from the airfield's traffic control tower, where experts superintend the coming and going of all the planes that land on the field. The signal at last is given, an officer on the ground gives the pilot a smart salute, and the great engines begin to roar. The plane taxis along the mile-long runway to the edge of the field, turns, comes back into the wind, picking up speed on the way, and finally leaves the ground behind and is off into the sky. Its flight is so smooth that no one inside could tell at just what instant it took wing.

As the earth falls away beneath them the passengers watch all the familiar landmarks shrink to the size of toys and then to a faint blur. For we are flying high to-day. Strong

winds along the earth's surface have made us go up more than two miles to a zone where the air is calmer. On our way up, the plane was rocked by the gale and occasionally shuddered as if it had had a tremendous blow. But up aloft it wings its way along as steadily as an automobile on a concrete pavement.

No one seems to feel dizzy, for no one has a sense of looking down from a great height. That is because the eye sees nothing to connect the plane with the ground and so serve as a measure of our altitude. For instance, there is no stretch of wall from sky to earth, as there is on top of a high building. The scenes passing below us look more or less like a moving picture, or perhaps like a great map that is rolled out under us. It no longer seems to be *our* earth.

Photo by American Airlines

The berths on an air liner are not very different from those in a Pullman car, as you may see from this photograph of a lower berth on one of our transcontinental lines. On an average the first passenger planes had fourteen berths all told.

The stewardess a registered nurse who has charge of the comfort of the passengers – now undoes the belts that are attached to the seats and were fastened around each passenger's waist before we took off. Whenever we land or take off, those belts will be fastened again, for air currents near the earth are likely to be rough, and the air line wants to protect us from being thrown over by a sudden lurch in case we should stand up at the wrong time.

People now settle themselves for their journey much as they would in a Pullman car. In fact if it were not for the absence of earth as one looks straight out from the windows it would be easy enough to think that this was a railway train. The roomy seats are ranged in much the same way on either side of a long aisle, with racks for hats and packages overhead. The stewardess has taken our outside wraps and has hung them up out of the way.

Science has learned to hush the noise of the motors as we hear it inside the plane, and to keep out all but one fifty-thousandth of the din that would otherwise be pounding into our ears. We can talk in perfect comfort. A pillow and blanket will be brought us if we want to tilt our seats back and take a nap. The stewardess adjusts the thermostat if the weather is cold, and we breathe the pure air of the heavens heated to just the proper temperature. If we want still cooler air we may open a little ventilator above our window and have the breeze directly in our faces. When we land at an airfield an air-conditioning unit will see that the air is kept warm and pure in winter and cool in summer.

And now we have time to ask ourselves questions about our marvelous bird and the men who fly it. The stewardess will tell us almost anything we want to know, and from time to time one of the pilots will leave the cockpit and come back into the passengers' cabin. He will always be glad to talk to us. It is not necessary for both pilots to be in the cockpit at all times, for a mechanical "pilot," known as the Sperry Automatic-Gyro, can pilot the plane as smoothly as the captain can, as long as there are no decisions to be made.

Moreover from time to time the captain will send us bulletins giving all sorts of details as to our flight– the plane's altitude, its speed, the outside temperature, and the weather at our destination. Meanwhile we have been figuring out all we can from the route map which the line provides – guessing

at our position from the cities and mountains and rivers and lakes that the map identifies. If we are a good deal interested, the stewardess will show us the avigation (ăv'ĭ-gā'-shŭn)—or air travel—charts that the captain uses.

As night falls we begin to ask ourselves how our pilots are going to find their way in the dark. But we do not have to wonder long. Beacon lights soon begin to twinkle along the route. As fast as we leave one behind we pick another up. And of course the stars are overhead to help to navigate the plane just as they help to guide a ship at sea.

Highways of Sound

But the pilot has a much simpler way to keep his ship on the track. Each airport we pass is sending out "highways of sound" by radio. The ship's radio picks up these signals, and the pilot can get them without even turning a dial. Over his ears is fastened a pair of ear phones connected with the plane's receiving set. As long as the plane is on its course he hears only a steady buzz. But let the wind swerve us a little to the right, and he at once hears "dah dee, dah dee," which in the Morse code is "dash dot, dash dot," the signal for "N." If the plane swerves to the left he hears "dee dah, dee dah," which is "dot dash, dot dash," the signal for "A." Those two signals are sent out, alternately timed, along radio "beams," or aimed broadcasts, that are directed like so many great arms from each airport. The broadcasting station is at the center of them all, and the beams are so arranged that the A beams form a straight line running in opposite directions from the broadcasting station and the N beams another straight line some distance from the first. This means that an A beam is always between two N beams and an N beam between two A beams. As the beams—which of course are not beams of light—leave the broadcasting station, they are only a few feet wide, but 100 miles away they fan out to a width of from 7 to 10 miles. However, the line along which two beams meet will always be a narrow one, and it is along this line that the pilot hears only a buzz—which in reality is the repetition of "dah," the dash signal, over and over. If he will but keep that steady reassuring buzz in his ears he will come to the airport just as surely as if he were driving an automobile along a road hemmed in by two high walls.

The Radio Direction Finder

Every forty seconds or thereabout the radio beam signal is broken while weather information is broadcast. At the same time the number of the ground station called a "range station" which is broadcasting the beacon is given, though if the pilot is in doubt as to his position he may find it out at any time by his radio direction finder. By means of this device he takes directional readings on signals from two or more different ground stations and then works out his position mathematically by means of those two stations. He can even check his findings by asking one of the ground stations to compute his position and report it to him a check that takes only a few seconds.

From time to time as he travels along his radio beam, the pilot passes over a second range station or crosses a beam coming from a station off to one side. Such a point, known as a "fix," will give him a third check and will tell him exactly where he is.

Why a Plane Can Never Get Lost

All this means that the plane is well provided with radio installations. It has five, all told. Besides equipment for the directional beam flying that we have just described, there is a radio direction finder, a reserve beacon receiver to be used in case of accident to the first one, and installations for two-way plane-and-ground communication. For the pilot is in constant touch with the ground, and the position of our plane and of every plane along the route is known to all the stations on the ground at all times. At stated points, called "check points," the pilot reports his position, the weather, temperature, time, and the length of time it will probably take him to arrive at the next check point. And both he and the flight control office keep a log of the progress of the plane for comparison with the flight plan.

By now the pure air and the thrill of adventure has given us an appetite, and we welcome the appetizing odors that come from

This pleasant little family is certain of being met at the airport on landing For though a plane may be long delayed, or even grounded, by bad weather, the passengers may telegraph their friends news of their whereabouts at all times and of the probable time of arrival all at the line's expense

the plane's kitchen where the stewardess is preparing the meal that she will serve to each person on a tray Except for the coffee, it was all cooked before we left the ground, but it has been kept hot and is now served to the passengers without extra charge, for meals are included in the price of the ticket You may even ask for something to eat if you feel hungry between meals

If we feel in a mood to read when dinner is over, the stewardess will bring us newspapers and magazines, or she can supply us with cards or other games If we want to write letters she will give us writing materials But we must be careful if we use our fountain pens for at our present altitude the ink flows much more freely than it does on the ground When bedtime comes the stewardess will make up our berths and we may go to bed whenever we like

Almost certainly that will not be before we make our first stop, for we shall want to see what happens when the plane lands Although we are still sixty or seventy miles away, the plane has already begun to descend, in this way sparing our ears the uncomfortable feeling that comes from too quick a change of altitude We hardly hear the motors now, and are a bit dismayed when we suddenly plunge into a heavy cloud How will the pilot see the field through all this fog?

In the pilot's ears the familiar on course signal is coming louder and louder now Then it suddenly stops We have entered the "cone of silence" which is just above the range station that has been sending out the directional beam he was following The pilot now must wait to get a signal from the airport dispatcher before he may land If other planes are landing at about the same time, he will be assigned an altitude at which he will continue to circle until he gets word to come in But we do not have to wait to night The signal comes at once through the ear phones and the pilot prepares to descend Already the stewardess has seen to it that we all have fastened our landing belts The first officer lets down the landing gear, which all this while has been drawn up inside the plane The wing flaps are dropped, and the plane slows up at once.

And now the pilot's eyes are fixed on a little dial that he has not even glanced at up to this moment. It will tell him whether he is on the "landing beam," which is being sent out from the airfield's "localizer," a radio device that is able to send out a strange "beam" that travels along the ground a little way and then bends upward at about the angle a plane would take in making a landing. That is the beam our pilot is following now. As long as he keeps the little dial's two pointers at zero he may know that he is safely following the landing beam. It is almost as if he were sliding down it toward the ground. The fog is dense, but there is not the slightest danger.

A light suddenly shines on the instrument board, set aglow by a vertical radio beam, or "cone," to give warning that we are nearing the field. Another light soon tells the pilot that he is now only forty feet above the ground. With scarcely a jar we settle down upon it. We have made a successful "blind," or instrument, landing.

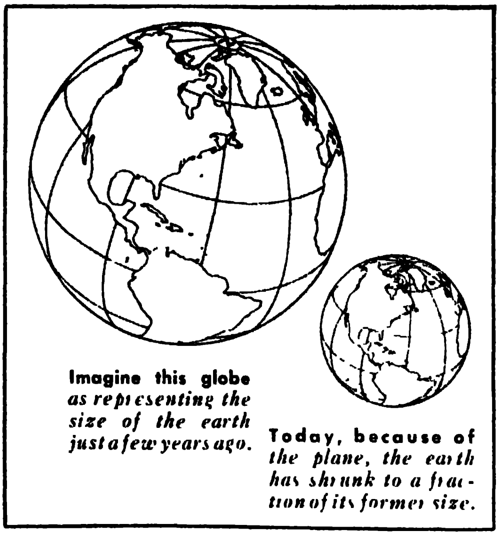


Photo by Consolidated Aircraft

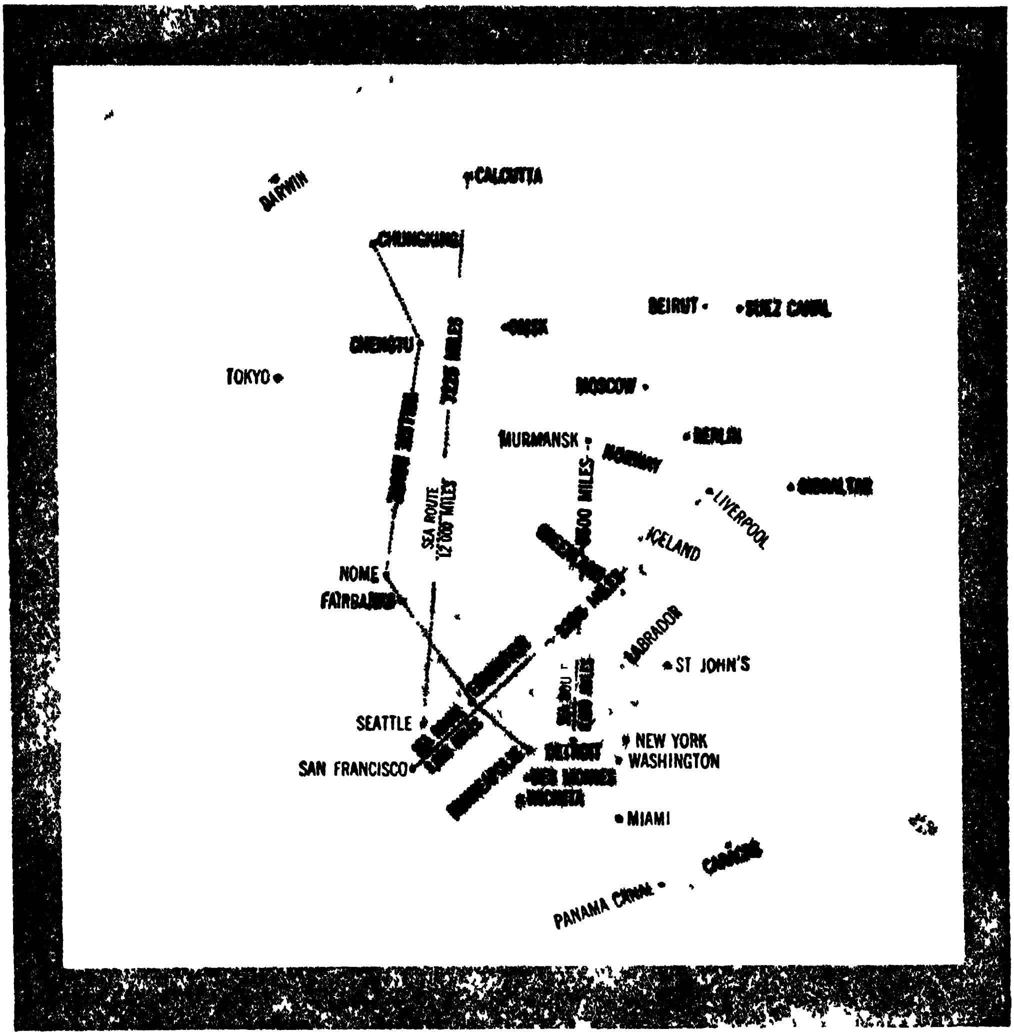
Which of the above is YOUR world? Do you still think of Paris and London, of Calcutta and Shanghai as being a long way off? Or have you learned to realize that in our modern world the Fiji Islanders are our neighbors?

How Planes Are Kept in Repair

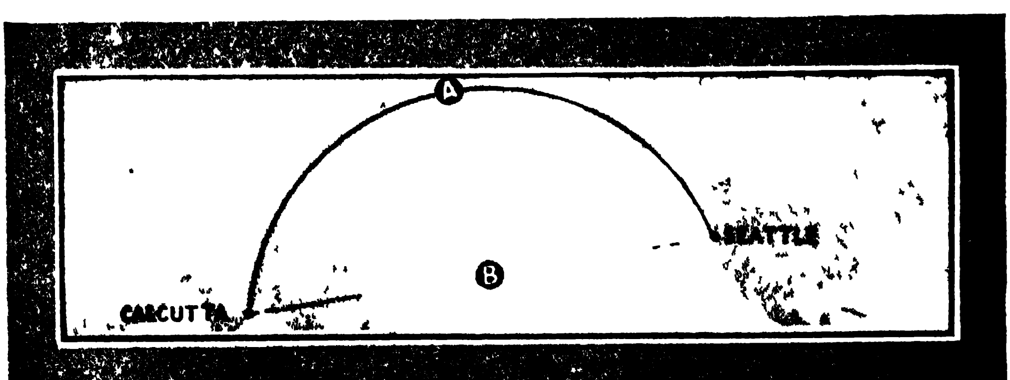
The instant we stop, mechanics rush out to check the plane and take care of its needs. At the end of our trip it will have a thorough overhauling, during which over 1,500 items will be checked. Nothing in it ever has a chance to wear out, for the instant a part shows wear it is replaced—and that in spite of the fact that parts are very expensive. Two carburetors on a plane like ours will cost $650. After every three hundred hours of flight the plane will go to the shop for a thorough testing. Propellers, wings, tail assembly, engines, undercarriage, and instruments are all removed. Even the hull is torn apart. Everything is examined as carefully as possible. Each engine part is washed in gasoline, and if it shows no flaw under the microscope it is tested in the magnaflux. This is an amazing device for magnetizing the inspected part, which has first been dusted with metallic dust. The process shows up flaws as a microscope cannot.

Of course the pilots are the most skillful men in their profession, and the most carefully picked. Nearly all of them have been trained in the Army, Navy, or Marine Corps. All of them have had at least two years in college, and many are college graduates. The captains have probably had well over 8,000 hours of flying experience, and the first officers over 3,000 hours. The Civil Aeronautics Administration, which is under the Department of Commerce and acts through the Civil Aeronautics Board, has given them a rigid examination. It will not allow them to fly more than eighty-five hours a month, and requires that they be paid according to a scale which gives the captain an income of about $8,500 a year. Of course among the first requisites for an air line pilot are sound health, steadiness, dependability, and sterling character. Every sixty days he is given flight tests and must pass a strict physical examination.

Any civilian who wishes to fly a plane must have a license from the Private Flying Division of the Civil Aëronautics Board, which has set up nine ratings for competence in pilots. The lowest of these is for student pilots, who must be at least sixteen years old and if they are under twenty-one must have the consent of parents or guardians before the license is granted. They must be Ameri-



This is the brave new world the airplane has brought us You must imagine yourself as standing on the North Pole looking down the slope of the earth as it falls away on all sides toward the Equator.



Photos by the Readers Digest

This is the kind of map we are used to. Ships going from Seattle to Calcutta travel along line B. But airplanes follow line A. It is the shortest route, as the map at the top of the page will prove.

can citizens, of sound health and good moral character, and must have had at least eight hours of flight with an instructor. They must also pass a simple examination.

Next comes the license for solo pilots, and above that the license for private pilots—one that is much harder to get. The candidate for it must not only meet all the requirements for the first two licenses, but must also pass a hard written examination on a number of subjects, such as weather forecasting, aërial navigation, and the use of instruments. He must have made at least thirty-five hours of solo flight, and must have had experience in cross-country solo flying. And of course he must pass a rigid flight test at the controls in various sorts of maneuvers. If the candidate has graduated from one of the various accredited aviation schools, his certificate will of course show that certain of the above requirements have been met. But the actual flight tests will never be omitted. The ninth license, and the most difficult of all to get, is the one our air line pilots hold.

Planes of the Future

No one knows exactly what the future has in store for aviation. We only know that the war, though it has been an interruption, has also given flying a tremendous impetus. The design of planes has improved beyond our wildest dreams. Already our great bombers are navigating the stratosphere, and some of our military planes have a speed of 600 miles an hour. We are told that before long we shall be able to take a plane in Los Angeles in the forenoon and go to bed the same night in London. Even as this is written planes are being built big enough to hold an eight-room house, with a wing load that has been greatly increased. And we are promised a little autogiro that will be as cheap as an automobile and as easy to operate safely. Even before the war it was possible to buy a private plane for as little as $1830—though of course luxurious private craft might cost as much as $60,000 or $80,000.

The New Airways

The airways of the future already exist in outline. We have the vast system that unites coast to coast and the Gulf with Canada. Supporting it are shorter lines linking city to city in each region. For instance, planes fly hourly between New York and Washington. But more than that, when the war began there already were one or two outlying "feeder" lines in operation little "neighborhood routes" along which planes went from village to village, swooping low to drop mail sacks and express packages wrapped in shock-proof cartons. Moreover, an ingenious arrangement of hooks and springs made it possible for them to pick up mail and packages as they went bustling by. Some day and the time is not far off passengers will take those sturdy little planes to go from village to village or perhaps from village to city. Two large air express companies were in operation when the war began, sending merchandise over air lines that already existed. At the war's end they had ready to hand giant transports of the sort needed to carry express and freight.

And all this is not taking into account the graceful little gliders that can be hitched together into a train and towed through the sky by a single airplane at slight expense

Our World in the Air Age

What the shape of life will be in the coming Air Age no one can quite say, but in hardly two decades the airplane has changed things for us unbelievably. It has added speed and convenience to our lives, and has annihilated space. It has brought the world together into a little compass, and has compelled us to realize that all men are our neighbors, whether we want them to be or not. The peasant in Europe is now in all practical ways closer to us than a man in the next state was twenty-five years ago. His diseases can be brought to us. His business can be shared by us. His ideas and discoveries become ours.

The airplane's services to humanity are manifold. Thousands of acres of precious forest have been saved by "spotters" in planes, who cruise about over great forested tracts looking for fires. When they see one they lead fire fighters to the spot and help direct the fight. Sometimes they carry the fighters in, and take them food, medicine,

and fire-fighting equipment. They even shower the flames with water.

Planes have helped save thousands of square miles of precious topsoil by sowing grass and mustard seed in burned-over areas. They have fought plant diseases by scattering insect powder to kill pests that attack bean fields or cotton fields or orange groves. They have been of great use in flood control and in helping to rescue people who are marooned. They take doctors to ships at sea or to distant places in the wilds to mining camps in Alaska or lumber camps in Siberia. And they often bring the ill or injured back to the hospital. Of course it is true that the airplane has not only revolutionized warfare but has added enormously to its horrors through the bombing of cities. But it is also true that it has saved the lives of thousands of wounded, who have been carried quickly from the battlefield to the comfort and skillful treatment to be found in big base hospitals. And though planes have bombed many defenseless ships at sea, they have also done magnificent duty in rescuing survivors.

How Airplanes Serve Us during Peace

In time of peace they rescue the shipwrecked and help catch lawbreakers. They aid in the work of ice patrol along the Atlantic ship lanes, and are of great use to the Weather Bureau by recording conditions in the upper air. Many remote regions, such as parts of Australia, Alaska, and Siberia, have been settled and worked because people knew a plane could bring in mail and goods and medicine. Explorers in planes have even been able to find new mines in Canada and Alaska, and have taken in machinery by plane. Other explorers have in a few hours visited the poles and tropical jungles that were weeks away by ordinary travel. It has even been possible to carry on archaeological research by plane, for a man from the air can clearly see the outlines of ruins.

But one of the greatest changes is still to come. That will be the change in our understanding of the globe we live on. The whole map is in process of reconstruction. Grown people do not understand their new world very well as yet. But to young people now in school it will soon seem altogether natural to think in terms of the Air Age. Most of us still measure distances as they were when traveled by train or automobile. But more than that, we still think of the habitable globe the globe as man has used it--as a series of continents stretched out east and west and centered about great ocean basins. For some forty centuries men have fought for positions of military importance on those continents or along the ocean lanes. Mountain passes, river valleys, straits, and ports - those were the points that made it possible for a nation to command a given region.

A New Map for a New World

Now we have seen that fortified harbors can no longer keep an enemy out at sea, that the control of a mountain pass cannot keep his planes from flying across the mountain, that to hold a narrow strait -or even a wide ocean may keep out warships but never can stop the giant bombers that lay waste a city in a moment. In other words, the map has been remade by this new invention. Political boundaries do not mean so much as they once did, and the snug continents, settled so securely in the earth's two hemispheres, are now open to hostile invaders.

The new map of the world, if it is to reflect the relationship of the various lands upon it, will have to be a round affair with the North Pole at its center. Grouped about the Arctic Ocean as the ancient countries were grouped about the Mediterranean Sea-- will lie crowding masses of land, all in deadly nearness to one another. Most of them are entirely in the Northern Hemisphere. Only two reach tapering arms south of the Equator, where the earth is covered with great stretches of water dotted with islands scattered far apart. But in the Northern Hemisphere the North Cape in Norway, seized by the Germans in 1940, is equally near by air to Seattle, Des Moines, and Washington, D. C. Grand Forks and San Diego are the same distance from the nearest point in Japan. And if we were to take the shortest route by air from the Panama Canal to Hongkong, the first large city we should pass over would be Pittsburgh or Detroit.

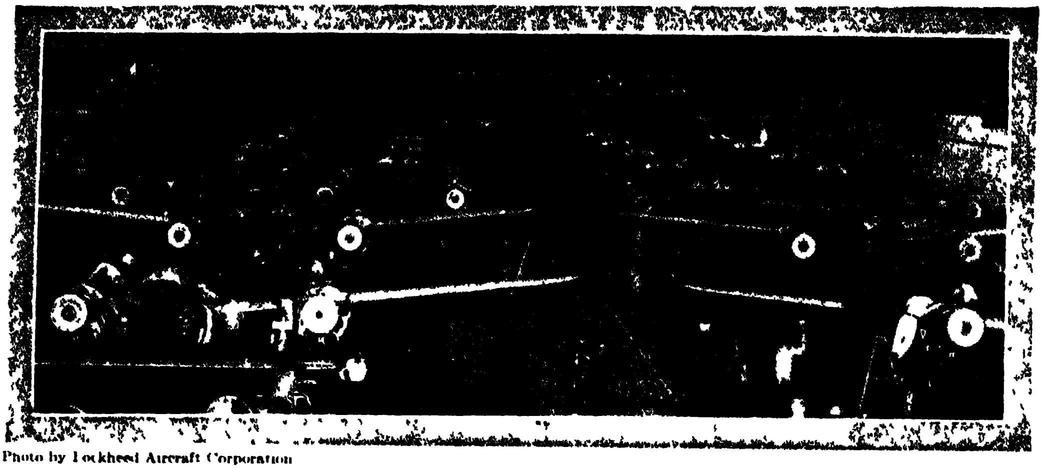


Photo by Lockheed Aircraft Corporation

Here is part of the assembly line for our Army's P-38, or Lockheed Lightning, used for fighting, heavy bombing, and long-range reconnaissance. With a speed of over 425 miles an hour, it can fight at treetop level or at 40,000 feet, has a bombing range of 1,700 miles, a bomb capacity greater than our early Flying Fortresses had, and mounts rockets with a firepower equal to the broadside from a six-inch cruiser.

GIANT BIRDS *of* GLASS *and* METAL

This Will Tell How We Make the Great Airplanes That Weigh Many Tons and Yet Can Fly

TWO things an airplane must have above all else if it is to live in the air. They are strength and lightness. The perfect plane will combine strength and lightness with high speed —that is, it will have an engine of great power and a design that will use that power to the very best advantage. Both engine and design will call for the greatest knowledge and ingenuity on the part of the plane's builders— for the arrangement of an engine's cylinders or the curve of a wing can add or subtract miles to a plane's hourly speed or to its rate of climb.

Naturally, with an industry growing as fast as the airplane industry has grown, the engineers and designers will try everything that looks promising to improve their product. They have experimented with many different materials to find the ones that are light and strong. There are planes with the frame made of wood and fabric, excellent materials for lightness. Many of the training planes used by our Army are built out of plastic-bonded plywood—thin layers of wood fastened together with plastic and at the same time molded, under heat and pressure, to their final form. This makes a substance stronger than steel for its weight. But at present the great majority of our planes are still made of metal, and those are the ones we shall talk of here, as they roll from the assembly lines in the great factories where mass production turns them out by the thousand.

All those planes consist of a metal frame over which is stretched a thin metal covering, or "skin," which gives the machine great strength and makes for speed as well. Older planes did not have this "skin" over all their surfaces. Much of the framework, especially in the wings, was out in the open, as any photograph will show. All the braces and struts caught the wind as the plane drove through the air, and slowed the machine considerably. When the wings were covered with a metal "skin," the plane at once took on speed and was a good deal stronger as well, for the rigid metal covering gives much more resistance to stress and strain. This newer type of design we call the "stressed-skin construction." The metal most com-

monly used for modern planes is a light aluminum alloy, with stronger, heavier metals built into vital places where the stress or strain is too great for aluminum. The braces in the frame are usually metal tubes, which are lighter than solid rods would be.

Engineers have designed this all-metal plane in such a way that in the factory it can be built in a large number of sections or units. Each department in an airplane factory performs only one operation or at most a very few, all of them especially assigned to it. Workers stay in one small area and work upon one small part, or a very few parts. And for that tiny specialty they have been carefully trained and have been given tools as nearly perfect as can be devised.

Those "tools" may be anything from superstructures known as "jigs" which correspond to the "cradle" in which a ship is built to huge hydropresses, drop hammers, metal cutters, welding machines, hand-drills, rivet guns, or common screw drivers and wrenches.

Photo by Lockheed Aircraft Corporation

Putting a new airplane into production takes time. For not only must the plane be designed. The machinery that is to produce it must be designed and built also. This interesting device is a rotary merry-go-round hydropress in operation at one of our country's greatest airplane factories.

What Is a "Sub-assembly"?

We shall not necessarily find these tools and the men who are working upon them — in the main plant. Often the various units or "sub-assemblies" will themselves be built in yet smaller sections at factories far from the main plant, and by smaller companies working as sub-contractors. There the little parts will be cut to proper size, formed by many and various methods to their proper shapes, heat-treated so that those shapes will be lasting, given chemical baths, and sprayed with a zinc chromate primer paint so that they will resist rust and action by the weather.

Then they will be carted off to the sub-assembly departments for which they have been ordered. Here they are seized by eager workers, placed on "jigs" or other structures, and there attached to one another in such a way that when they have all been put together, there comes out of the sub-assembly department a brand-new wing tip or center section, or perhaps a fuselage (fū'zê-lâj) or body—a tail assembly, or an engine mount.

Those sub-assemblies are then carried by truck or cart to what is the biggest room in an aircraft factory—the final assembly. Here is the great hall where the airplanes are born. It is impossible to say where an airplane actually started—whether the nose came before the tail or the wing before the fuselage. They all were being built at the same time in different rooms or departments or factories by different people, most of whom had no sort of knowledge of one another. But here are the finished parts, all together in final assembly. They do not all arrive at once, of course. As the fuselage moves down the long final assembly hangar, it is "mated" first with the center section, then with the wings and tail, then with the various control surfaces, instruments, engines, propellers, and miscellaneous parts, each of which arrives at the proper time on the line to achieve a smooth, continuous flow of production.

Inspectors pass up and down the lines, constantly inspecting every piece of work performed by every worker. Not a rivet—and there are some quarter of a million of them in certain Army planes—not a bolt, goes into a modern airplane until it is carefully inspected by a trained expert. He blue-pencils any imperfect work, which then must be done again.

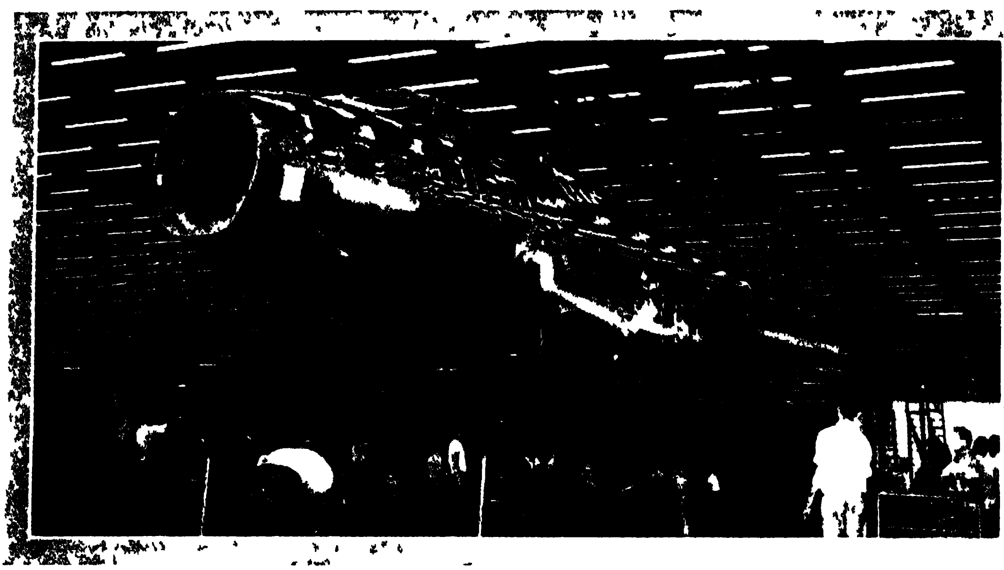


Photo by Lockheed Aircraft Corporation

One of the monster B-17 bombers is moving by overhead rail down the assembly line. This completed fuselage will win its wings in the jig at the next station on the long assembly line

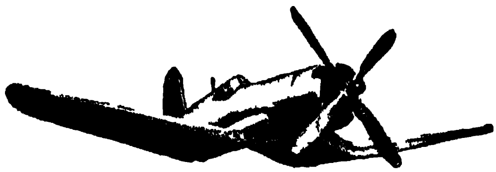
For a single weak part may result in a crash. Often parts will be examined under the microscope or perhaps the X ray to see if there are flaws.

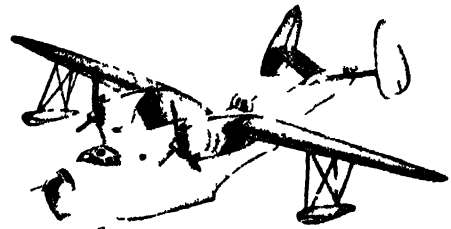
Who Builds Our Airplane Engines?

Engines are rarely made in the plant where the rest of the airplane is assembled. Huge engine companies build those giant power plants, which are then carried by train or bus, or sometimes even by air, to the point of assembly with the airplane. The aircraft manufacturers either buy the engines from the companies that make them, or the contractor who places the order for the planes buys the engines himself and has them carried to the place of assembly and mounted in the planes. There are only a very few important builders of airplane engines in the United States, though many automobile manufacturers are helping those mother companies turn out thousands of engines fast enough to keep pace with the output of frames. Naturally the best airplane engine is one that combines the most power with the lightest weight and the smallest consumption of fuel. To-day even our largest engines weigh only a pound for each horsepower developed.

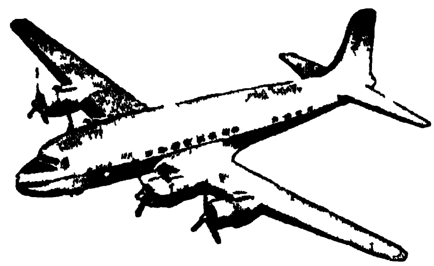
The use of a special gasoline known as high octane (ŏk'tān) gasoline in airplane engines has more than doubled the horsepower of the engine per cylinder. Some of the finest airplanes would not be able to leave the ground if they had to use the gasoline that is burned in automobiles. A "self sealing" gasoline tank, with a lining made of a composition of rubber and fiber prevents leakage even when the tank is punctured by a good sized bullet. The lining swells and stops the hole.

In 1945 our designers perfected the Lockheed Shooting Star, or P 80, a fighting plane driven by jet propulsion. Elsewhere we have told what jet propulsion is. Planes driven by it will soon fly at 1,500 miles an hour at levels ten or more miles above the earth. There the weather is always fair and the calm air is so thin that it offers no resistance. The higher the flight the better the engine will work. Later, when we have perfected the rocket plane - working on the same principle—we shall fly at almost any height—100 or 150 miles up. Our speed will be practically unlimited, say, 100,000 miles an hour. A jet-propelled plane flies very smoothly, without noise or vibration, and the pilot feels little strain.



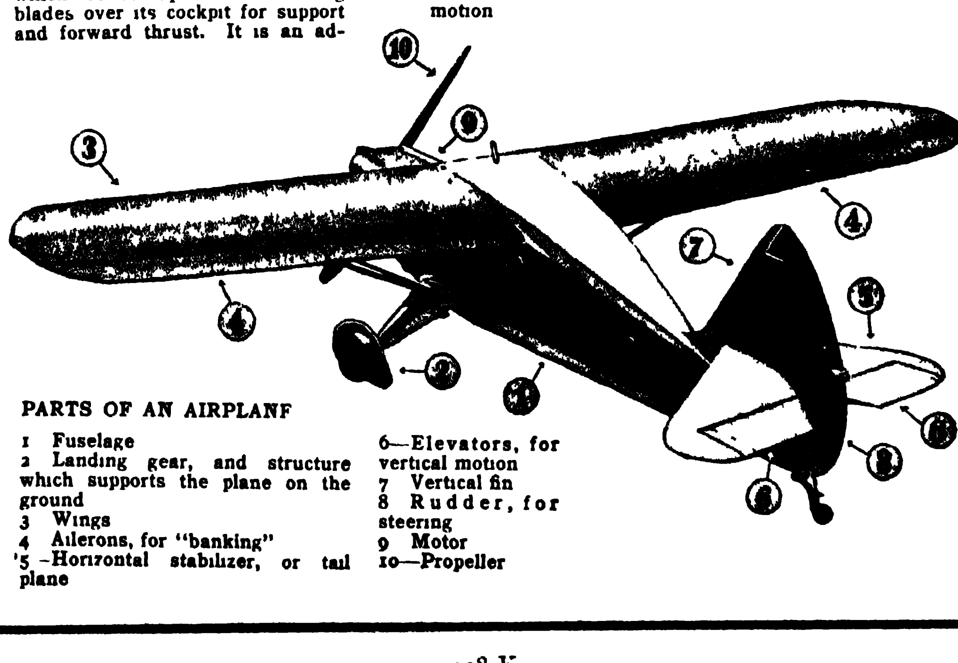


Left, a low-winged monoplane with single engine and inverted gull wings. Right, a twin-engined flying boat with gull wings.



Left, a low-winged monoplane with wings tilted slightly upward Right, a giant four-motored passenger transport plane

Left, a jet-propelled plane of the type developed by the United States Army at the close of World War II Right, a wingless helicopter, which relies upon the whirling blades over its cockpit for support and forward thrust. It is an advance over the autogyro, which had wings for support and a propeller in front for forward motion



PARTS OF AN AIRPLANF

1 Fuselage
2 Landing gear, and structure which supports the plane on the ground
3 Wings
4 Ailerons, for "banking"
5 -Horizontal stabilizer, or tail plane
6—Elevators, for vertical motion
7 Vertical fin
8 Rudder, for steering
9 Motor
10—Propeller

The airplane engine is the highest type of internal-combustion engine yet produced. Usually it is radial in type and air-cooled—that is, the cylinders, instead of being "in line"--or placed one behind the other--are arranged around a hub, like the spokes of a wheel, and so can all be cooled by a steady flow of air that is part of the current streaming over the fast-moving plane. However, there are a few engines --notably the Allisons used in certain of our Army fighters —that are cooled by a liquid called prestone and are in-line engines. Sometimes these engines have cylinders arranged in an upright or an inverted "V," sometimes in the shape of an "X."

Photo by Lockheed Aircraft Corporation

Turning out war planes is a race for time. Here expert workmen are toiling at top speed to attach the motor in the great four-engined bomber shown in the preceding photograph.

Unlike the automobile engine, which rarely has to do the most of which it is capable, the airplane motor often is called upon for one hundred percent, and even more, of its rated ability. Engine parts which must stand up under such a strain often are made of rare and precious metals. The ones commonly used for such parts are alloys of aluminum, steel, magnesium, and other metals, which are cast, forged, and heat-treated. Nickel steel, nickel iron, lead-silver, and lead-copper are much used. Molybdenum, (mô-lĭb'dē-nŭm), babbitt, aluminum bronze, stainless steel, and stellite are others. Parts are nitrided, chromed, and sometimes micro-finished to make them work perfectly. All the larger planes have more than one engine.

On other pages we have described the simple principle upon which an airplane is made to mount into the air and push its way along through that gas, which seems light enough to us as we walk through it but which can offer tremendous resistance at the speed an airplane attains in flight. Of course a plane would be nothing but so much dead weight of metal were it not for the motor. But the motor, throbbing with power, must somehow be made to transfer its energy to the airplane. It must supply to the plane one of the four major forces that act on a plane in flight – the force that is known as "thrust." An engine can do this by means of the "propeller," the windmill-like affair usually set on the nose of the plane. The propeller is what pulls the plane through the air or pushes it if the propeller is at the rear. By attaching the propeller to a rotating shaft that is kept turning by the engine, we can use the engine's power to send the plane along. In other words, the rotating shaft hitches the engine to the plane just as truly as a harness hitches a horse to a wagon. Through this rotating shaft the engine supplies horsepower to the propeller, which is a device for absorbing what is known as "brake horsepower" and converting it into "thrust horsepower." Brake horsepower is the actual horsepower delivered by the engine at the end of the crankshaft.

How the Propeller Does Its Work

The propeller, which puts all this horsepower to effective use, has two or more twisted arms called "blades." Modern high-powered airplanes usually have three. A propeller blade may be likened to an "airfoil," the name we give to any airplane surface that is designed in such a way as to use the air for the purpose of keeping the plane under control. Ailerons (ā'lē-rŏn), wings, and rudder are all airfoils. The propeller is shaped so that it will serve the same purpose and get the same result—except that while the force of the air against a wing is vertical and so *lifts* the plane, the force of the air against a propeller that is turning on its hub

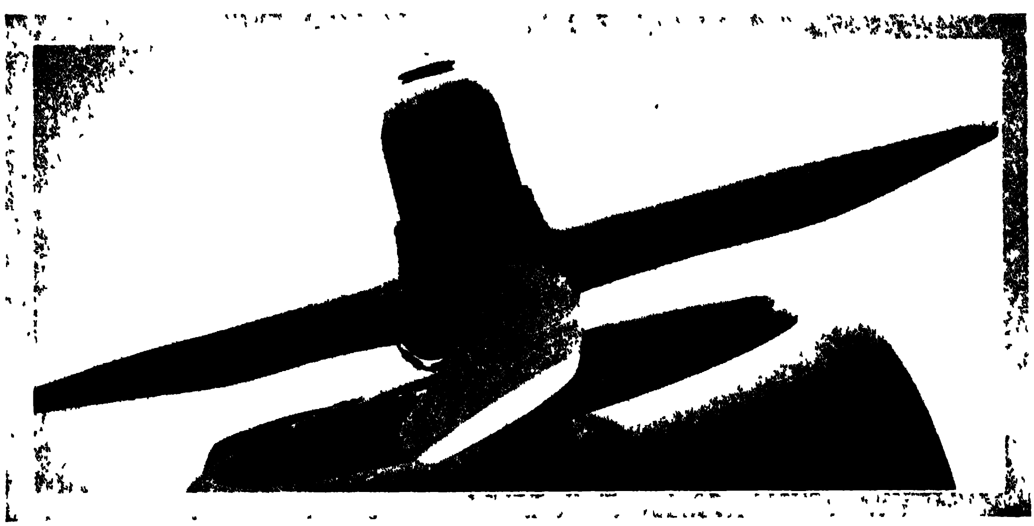


Photo by Lockheed Aircraft Corporation

An airplane propeller is a beautiful thing. Its clean lines and subtle curves remind one of a seagull's wings. This photograph gives us an excellent idea of the twist that makes a blade "bite" the air.

at a high speed is horizontal and so thrusts or propels the airplane *forward*. The force lifting the wings counteracts the force of gravity, which pulls a plane down; the propeller counteracts what we know as "drag."

The Forces Causing "Drag"

Drag has an interesting cause. As a plane rushes through the air it meets with resistance from the air and tends to leave a hole behind it—that is, it is going so fast that the currents of air flowing over it from nose to tail fin cannot flow together fast enough behind the plane to prevent the forming of a vacuum (văk'ū-ŭm)—a place where there is no air, or at least almost none. We have told elsewhere what a powerful pull a vacuum exerts on whatever surrounds it. We see the principle at work in a vacuum cleaner. The vacuum at the end of a moving plane pulls on the plane and drags it back. The propeller must overcome the dragging forces before it can send the plane ahead.

Because the propeller travels forward as it revolves, in much the way that a screw bolt travels forward through a nut, a propeller is sometimes called an "air screw." Since the propeller blades are set at an angle—called the "propeller pitch"—they scoop air toward them as they spin. This carries them forward through the air. Thus, just as the turning of a bolt forces it farther forward through the nut, so the turning of the "air screw" forces it—and the airplane with it—through the air.

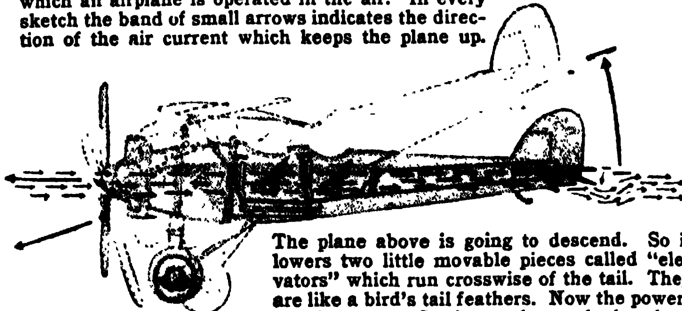
On a "controllable-speed propeller" the angle, or pitch, at which the propeller blades are set can be adjusted so that they will "bite" the air more deeply or less deeply. This has the same effect as increasing or decreasing the number of turns in the thread of a screw. For taking off, when a great deal of power is necessary in order to raise the plane from the ground, the blades are set at a low pitch and are turned at high speed. But when the plane has straightened out in the air, the blades are set at higher pitch and can then be revolved more slowly without reducing the speed of the plane. In other words, a single revolution at high pitch will carry the plane farther forward than a revolution at low pitch will. Often this adjustment of the blades is made automatically.

What Holds a Plane in the Air?

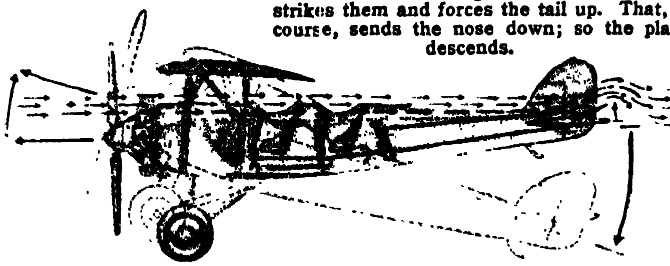
The propeller blades as they whirl create a rapid flow of air over and under the wings of the plane. That flow of air strikes the under sides of the wings with a great deal of force. But at the same time, if the wings are properly designed, the current that strikes their front edge is turned upward, and because it

This page shows the very simple principles upon which an airplane is operated in the air. In every sketch the band of small arrows indicates the direction of the air current which keeps the plane up.

Like a kite, an airplane is held up by a current of air striking the under side.

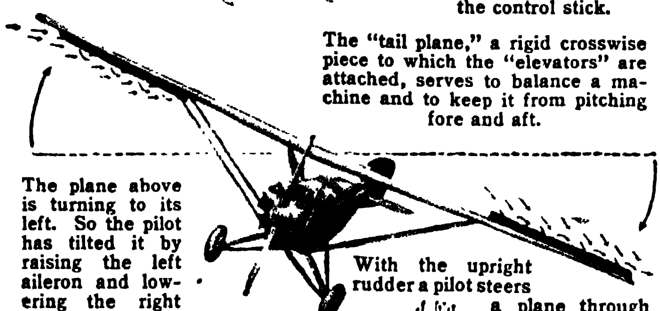


The plane above is going to descend. So it lowers two little movable pieces called "elevators" which run crosswise of the tail. They are like a bird's tail feathers. Now the powerful air current flowing underneath the plane strikes them and forces the tail up. That, of course, sends the nose down; so the plane descends.



The plane on the left is going to rise; so it raises its "elevators," at the tail, and the current of air flowing from front to rear along the top of the plane strikes them with such force that it pushes the tail down. As the tail goes down the nose comes up and the plane mounts. A plane's elevators are like two movable flaps attached to the "tail plane" on either side of the rudder. The pilot operates them by pushing or pulling at the control stick.

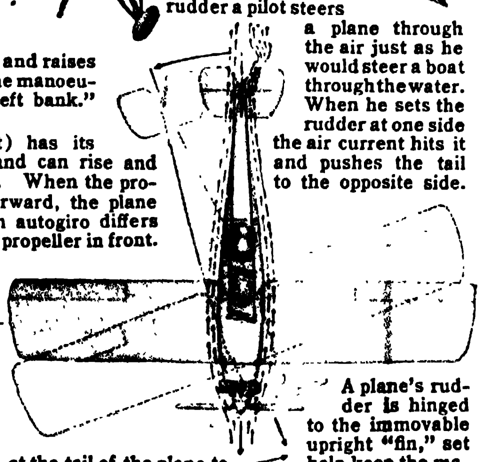
When a plane goes swiftly round a curve it must lean to the inside of the curve, just as a skater does. To "bank" in this way the pilot moves the control stick sideways and so operates two crosswise movable flaps, called ailerons, attached to the rear of the wings—just as the "elevators" are attached to the tail plane. When one aileron is raised, the other is lowered. So the air pushes one wing down and raises the other up.



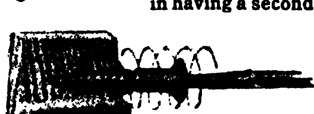
The "tail plane," a rigid crosswise piece to which the "elevators" are attached, serves to balance a machine and to keep it from pitching fore and aft.

The plane above is turning to its left. So the pilot has tilted it by raising the left aileron and lowering the right one. This pushes the left wing down and raises the right wing. The manoeuver is called a "left bank."

A helicopter (left) has its propeller on top and can rise and descend vertically. When the propeller is tipped forward, the plane moves ahead. An autogiro differs in having a second propeller in front.



With the upright rudder a pilot steers a plane through the air just as he would steer a boat through the water. When he sets the rudder at one side the air current hits it and pushes the tail to the opposite side.



The propeller, set like an electric fan on the front of the plane, acts like a big screw which bites its way into the air as a screw bites its way into wood. It drags the plane along after it. The engine turns the propeller. It is the rapid forward movement of the plane that creates the air current necessary to hold the machine up.

A plane's rudder is hinged to the immovable upright "fin," set at the tail of the plane to help keep the machine in a straight path. The wheeled landing gear in front and the tail skid underneath at the rear help the plane to land and take off.

cannot bend sharply down again a vacuum is left on top of the wings just behind the point where the air current shoots up. Naturally this vacuum tends to suck the wings upward just as the vacuum at the tail of the plane pulls the plane backward. Since the air pressure against the top of the wings is greatly reduced, the current striking on the under side of the wings is able to push the wings up and those two forces acting together hold the plane in the air.

When the propeller has drawn or pushed a plane down the runway on the airfield with sufficient forward speed to create a lift that will overcome the pull of gravity, the plane has then attained what is called "flying speed" and it takes off from the ground. Strange as it may seem, the vacuum on top of the wings contributes a good deal more lifting power than does the current pushing against the under side of the wings. About two-thirds of the "lift" comes from the suction of the vacuum, one-third from the direct force of the current pushing up from below. Of course both those forces depend on the forward motion of the plane through the air. Once that is stopped, there is nothing to hold the plane up and it will fall like a lump of lead. And when the smooth flow of the air over the airfoils is disturbed, the plane is likely to "stall" and go into a tail spin. You will notice that the four major forces at work on a plane operate in pairs, "thrust" against "drag" and "lift" against the pull of gravity.

The same flow of air over and under the wings provides the force by which the plane is controlled. For in this respect the stream of air on the airfoils acts exactly like a stream of water on the rudder of a boat. The various movable surfaces - the ailerons, the rudder, the elevators —all are controlled by the pilot from the cockpit. The control lever, which is operated by hand, is either a straight rod—familiarly known as the "joy stick"--or a wheel. The rudder bar usually has pedals and is operated by the feet. Many airplanes, especially large ones, have two and even three tail fins and rudders, to give greater steadiness. The ailerons, which control the tilt of the plane, work in unison, each moving in the opposite direction. If the plane rolls, with one wing sinking lower than the other, the pilot pushes the control lever toward the high side. This brings the plane back on an even keel by turning the aileron down on the low side, in that way giving the low side a stronger lift.


Photo by Lockheed Aircraft Corporation

Our giant bomber the B17, or Flying Fortress - has at last won its wings. The inter-wing section has just been moved up by overhead rail and is being mated to the fuselage on the final assembly line.

But even though our airplane may be able to leave the ground and stay in the air without falling, it still may not operate smoothly and efficiently. It may not have speed. The "drag" may hold it back, while other planes, with no more power in their engines, will outdistance it with the greatest ease. If so, there is something wrong with the design of the plane. It has not been "streamlined."

The Importance of Streamlining

Everywhere in nature we see examples of streamlined shapes. Birds and fish are streamlined to beautiful perfection. And the fuselage of an airplane is shaped very much

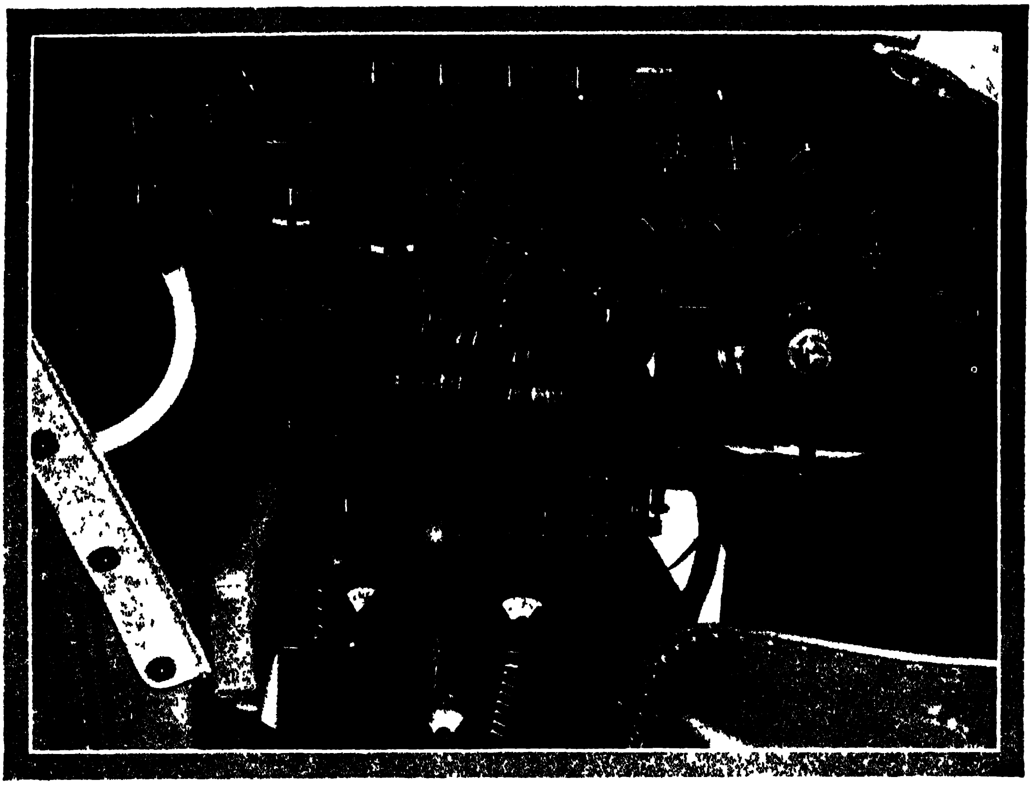


Photo by Lockheed Aircraft Corporation

If you were pilot of a Lockheed Hudson bomber this is what you would see before you in the cockpit. You would know every dial and control, and would handle them all with instant decision.

like the body of a fish. But more than that, all the exposed parts of an airplane, if the craft is to be completely efficient, must also be streamlined. This includes struts, engine housing, the pilot's cockpit, and the landing wheels, which in most planes to-day can be drawn in and folded up inside the plane. It even includes the very rivets that hold the skin to the struts of the plane. When the old "dimple" type of rivet was replaced in 1939 and 1940 by counter-sunk rivets flush with the surface of the skin, twelve to thirty miles an hour were added to the speed of airplanes of the types on which the change was made. Tapering the body toward the tail and rounding the front helps to do away with drag.

A Great Advance in Design

It may be that our plane, though streamlined, is slow because it has a low "wing load." The wing load of a plane is the ratio between the plane's weight and the area of its wings. When that ratio is low—that is, when there is a large area of wing surface in comparison to the weight of the plane—a great deal of the engine's power will be spent in overcoming the resistance of the air that flows against the wings. But when the wing load is high the same engine can send the plane through the air much faster. Between 1932 and 1942 the speed of planes increased by fifty percent, largely because airplane designers had learned how to increase the wing load. That is said to have been the most important single advance in airplane construction over a period of some twenty years. A fast plane may weigh more than fifty pounds for every square foot of lifting surface. It is easy to see that an airliner that can carry a heavy load without increasing its power will make money for the company that owns it, and eventually will bring down the cost of air travel.

There is much more to flying an airplane than merely knowing how to operate the controls. The pilot must know in what direction he is flying, how high and how fast he is flying, how much fuel he has left, how much he is drifting off his true course, whether his engines are overheating, whether he has sufficient oil pressure, and many other fine points of aërial navigation, including the knowledge of instruments and the special training which make it possible for him to make a "blind landing" at night or in heavy weather, when he cannot see his landing field. He can perform this amazing feat merely by watching the instruments that are all around him in the cockpit. A glance into the control cabin of a modern skyliner reveals a bewildering maze of instruments, dials, and controls. One type of modern "luxury liner" lists no less than 103 such devices, which must be watched constantly by the pilot and co-pilot or navigator.

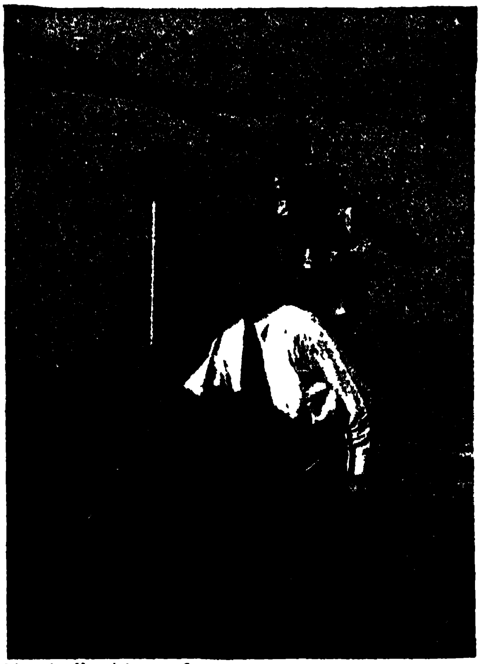


Photo by Hoppi-Copters Inc.

The Hoppi-Copter, a one-man helicopter, is the nearest man has come to wearing wings. It can fly 200 miles at 60 miles an hour without refueling.

A Plane's Amazing Instruments

All aircraft instruments belong to one of three main groups flight instruments, engine instruments, and navigation instruments. Among the most important in the first group are the air-speed indicator, the turn-and-bank indicator, and the climb indicator. The "air-speed indicator" registers the speed of the plane in relation to the air through which it is moving. It does not show the speed in relation to the ground. For instance, the dial of the air-speed indicator may show that the plane is moving at the rate of 250 miles an hour, but if the plane is flying directly against a wind of 25 miles an hour, the plane's actual speed relative to the ground is only 225 miles an hour. The force with which the air strikes the plane is measured by means of what is called a Pitot (pē'tō') tube, which is attached to a wing support or to the nose of the airplane. This is a somewhat complicated device that is of great importance to the pilot.

It is practically impossible for a pilot, relying on his senses alone, to hold an airplane on a straight course during a "blind flight," when he is hemmed in by fog. At that time a "turn-and-bank indicator" will at once warn him if he is swerving ever so little from a straight course. The two main parts of this instrument are the turn indicator and the bank indicator. The turn indicator is controlled by a gyroscope, which we have described elsewhere. The bank indicator consists of a ball inclosed in a curved glass tube filled with liquid. The liquid merely serves to slow up the motion of the ball. If the wings of the plane tip to the right, the ball will roll to the right also; and if they tip to the left the ball will roll to the left. When a turn is properly made the ball rests quietly at the center of the curved glass tube. If the pilot does not bank properly upon a turn he is in danger of "slipping" into a fatal tail spin.

The "climb indicator" shows the rate at which an airplane is gaining or losing altitude. It uses the principle upon which the barometer is made, and relies for its findings upon the fact that the higher one goes above the earth the lighter is the pressure of the air.

Another important flight instrument is the "altimeter" (ăl-tĭm'ē-tēr), which also works on the principle of the barometer. It indi-

cates the approximate height of the plane above a previously chosen point, which may be sea level or the point from which the plane started or any other desired point. To interpret this kind of altimeter the pilot must know the air pressure on the ground beneath him. Of late the altimeter has been greatly improved. Formerly many accidents occurred because planes crashed into the side of a mountain when the pilot supposed he was high enough to clear the summit. The new "absolute altimeter" sends out a radio wave which is reflected back from the earth. A very delicate instrument measures the length of time it takes for the radio wave to make the circuit and can in this way indicate the height of the plane above the ground.

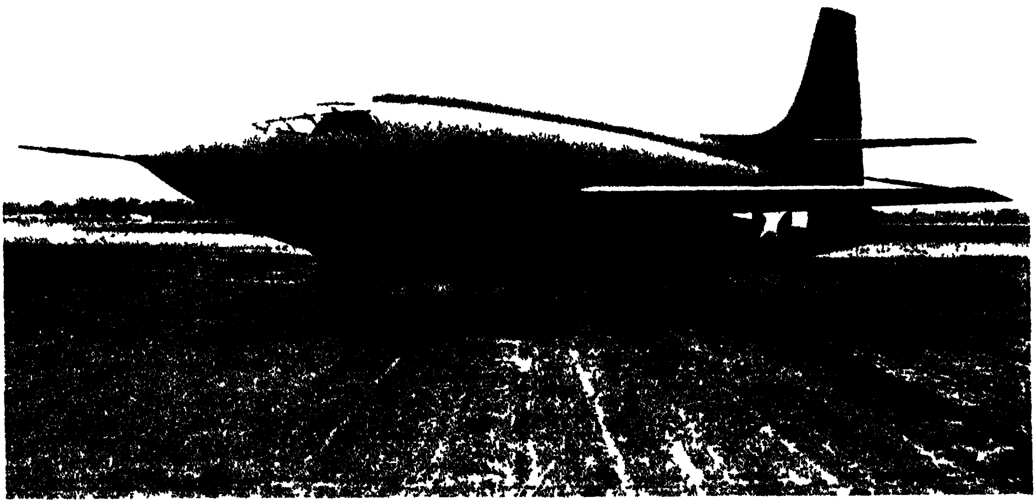
The "artificial horizon" controls the direction of flight when the actual horizon cannot be seen, and is really a kind of adjunct to the turn-and-bank indicator. It shows the degree of bank and the amount by which the nose of the plane is tilted up into the air or turned toward the ground.

Among the engine instruments are the tachometer (tȧ-kŏm'ē-tẽr), which tells how fast the engine is running by showing the number of times the crankshaft revolves in a minute; thermometers, which show how hot the engine is; pressure gauges, which show whether the oil system is being kept at a pressure to operate the engine; and the gasoline gauge, which shows how much fuel remains. Navigating instruments include the magnetic compass; the radio compass; the sun compass, which can be used over the Pole, where the magnetic compass will not work: and various other instruments that are used for navigation both at sea and in the air.

A very important part of an airplane's equipment is the de-icing device, which prevents ice from forming on the wings and propeller, where it not only adds to weight and air resistance, but deforms the wings so greatly that the air currents are swerved from their proper course and the plane gets out of control. To avoid this the wings are fitted with "overshoes" made of rubber which has been treated with an oil that will not let ice form on the rubber surface. But more than that, those rubber overshoes can be inflated to break any ice that may be held in place on the wings by the current of air passing over the plane. A light warns the pilot that ice is forming, and he turns on a pump to inflate the overshoes. Another device injects under the ice a chemical which is able to dissolve it.

Because the air at very high altitudes is too thin to make an explosive mixture in the engine strong enough to drive the plane as high as the pilot may want to go, a "supercharger" must be used to compress the air till it is as dense as the air at lower levels. In this way our newest planes can mount to 55,000 or even 65,000 feet. Sealed cabins make it possible to maintain a comfortable air pressure for passengers, and two propellers rotated in opposite directions on a single engine shaft can send against the wing surfaces a stream of air heavy enough to buoy up the plane even though the surrounding air is very thin.

At the close of the war our Navy brought out the Hellcat, a pilotless high-powered fighting plane. It can take off, fly, fight, and land by remote radio control, with television to let the operator see what is going on. One "pilot," seated on the ground before a control panel, takes the plane off, retracts the wheels, and starts it circling over the field. Another operator in a mother plane flies the Hellcat on its mission, and the first operator lands the plane on its return.



This plane, the XS-1, has flown at nearly 2,000 miles an hour. It is experimental, as the "X" in the title shows, and though it belongs to the United States Air Force, it will never go into service. This was the first plane to exceed the speed of sound (1947), that is, to fly at "supersonic speed." When a plane reaches the speed of sound, "transonic speed," violent forces there can tear it apart. Supersonic speeds are smoother. The speed of sound varies with altitude. It is 763 miles an hour at sea level at 59° F. and about 660 miles at 40,000 feet. We speak of the Mach (Mak) number—or M number—of a plane's speed, meaning its percentage of the speed of sound, which is 1. M-0.5 is half the speed of sound. Transonic speed—"across sound"—lies between M-0.8 and M-1.2. Planes that reach these speeds all have very thin wings, often swept back. The XS-1 is shaped like a rocket and burns liquid oxygen and ethyl alcohol. It is designed to travel at 1,500 miles an hour. Its rocket motors weigh only a tenth of what jet motors would weigh.

THE PLANE *of the* FUTURE

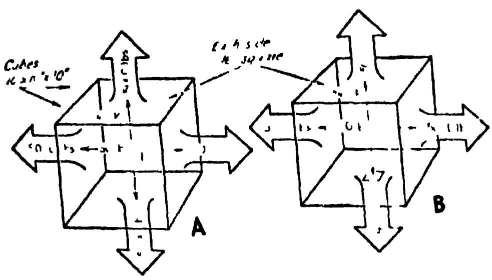
How Rocket and Jet Propulsion Can Carry Us through the Air at Speeds That Seem Fantastic

WORLD WAR II was won by the nations that were able to outfly, outmaneuver, and outproduce their enemies in the battleground of the skies. For six years during that desperate struggle the best aviation engineers in all the fighting countries worked to improve their engines, for each one hoped that his own country might be the one to have the advantage in speed. But the best any of them could do was to squeeze an additional 50 miles an hour out of the ordinary type of airplane engine. Speeds much above 450 miles an hour seemed out of the question. It was not until the closing days of the war that engineers turned to an engine operating on a new principle—that is to say, new in aviation, for the principle had been known before the birth of Christ.

The reaction engine—as the new types of rocket and jet engines are called—is simple enough. Anyone can operate a reaction engine in less than a minute. Merely inflate a toy balloon, hold the nozzle closed between your thumb and forefinger, then release the balloon. Notice how the balloon scoots away, darting and twisting until it expels all the air and is flat. What propelled the balloon?

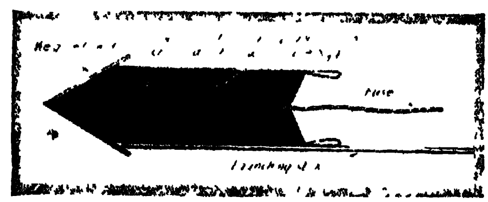
To help understand how reaction engines work, imagine a cube measuring 10 inches

on each side and filled with compressed air. Let us also assume that the pressure inside the cube exerts a force of 50 pounds on each square inch of box. Since each face of the cube has an area of 10 times 10, or 100, square inches, the total force acting on each face from inside the cube amounts to 5,000 pounds. The forces acting up, down, and sideways are all equal.



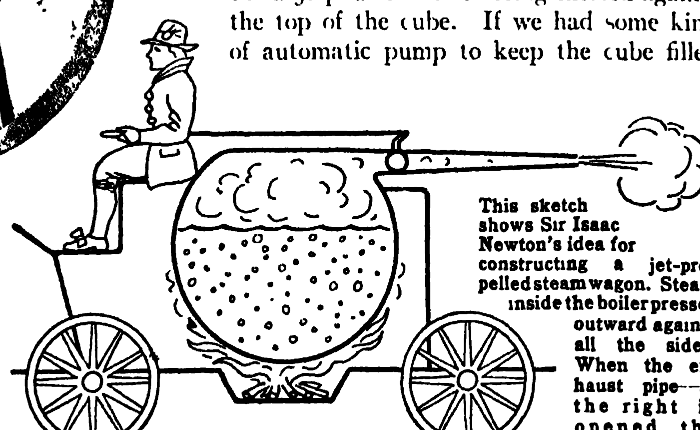
This diagram will make clear to you the principle of jet propulsion. Compressed air inside cube A is pushing outward against every face with a force of 5,000 pounds, or 50 pounds against each square inch of surface. Now cut a square inch out of the bottom face—as in cube B. The pressure against the bottom is now 50 pounds less than against the top, so the cube moves upward with a lifting force of 50 pounds.

Now suppose that, with the cube suspended in mid air, we suddenly cut one square inch out of its bottom face and in this way make an opening in it. The lower surface, having lost one square inch of its area, now measures only 99 square inches. The force against the bottom face of the cube therefore becomes 4,950 pounds—or 99 square inches multiplied by 50 pounds for each square inch. The forces on the side faces still balance one another, but the upward force of 5,000 pounds is not balanced by the downward pressure of 4,950 pounds. This lack of balance of the forces pressing outward from inside the cube will now result in the cube's moving upward under the pressure of that extra 50 pounds that is being exerted against the top of the cube. If we had some kind of automatic pump to keep the cube filled with air under pressure, the upward motion would keep on indefinitely.

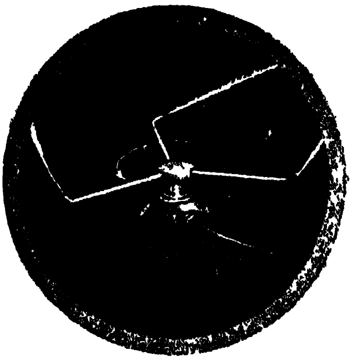


The sky rocket illustrates the principle of rocket propulsion. It carries all its own fuel and oxygen as well. Once the lighted fuse sets the fuel on fire, the oxygen inside the rocket keeps the fire burning.

It is said that Hero of Alexandria originated the idea of the reaction engine as far back as the first century after Christ. Steam generated by water boiling inside the hollow drum rushes into the hollow metal ball and then out of the nozzles. The release of steam through the nozzles reduces the pressure inside the ball at those two points. But everywhere else inside the ball the steam is still pressing outward. That unequal outward thrust starts the ball spinning, much as a pinwheel spins.



This sketch shows Sir Isaac Newton's idea for constructing a jet-propelled steam wagon. Steam inside the boiler presses outward against all the sides. When the exhaust pipe—at the right is opened, the pressure against the front of the boiler is greater than that against the rear, and the wagon is driven forward. The driver can stop the wagon by pushing backward on the pole he holds. This closes the exhaust pipe and so equalizes the pressure inside the boiler.



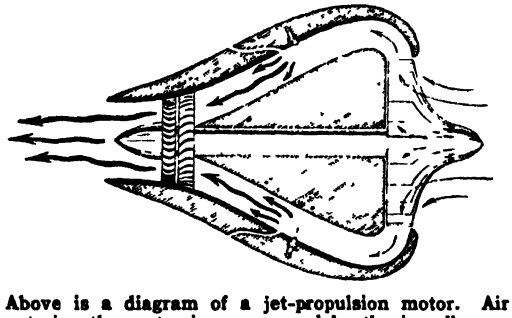
Above is a lawn sprinkler of the reaction type. As the water rushes out of the openings an uneven pressure is created inside the top of the sprinkler, and that pressure or backward push keeps the device whirling as long as the water rushes from the nozzles.

If our camper is not careful he will land in the lake. For as he leaps forward, his feet will push backward against the canoe just as the water in the sprinkler pushes backward when it rushes from the nozzle. The canoe will then shoot away from the dock.

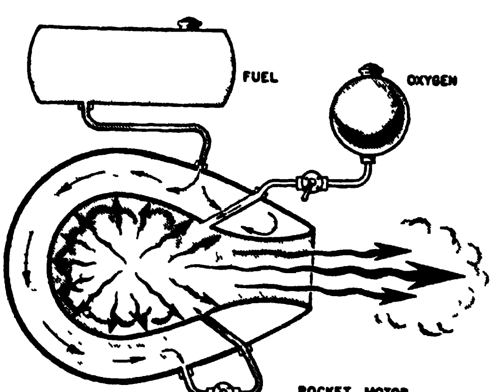
It is hard to make progress on slippery ice. Our man is trying to take a step forward, but to do so his foot must push against the ice. Since the ice is slippery it does not push forward against his foot as hard as he pushes backward. So he is unable to move ahead.

The ordinary skyrocket was the first successful operation of the reaction principle that we have just described—and the operation was almost continuous. The rocket has its fuel packed into a tube behind the head. When the fuse train sets the powder on fire, the burning lets loose huge volumes of heated gases. Those gases, which are under pressure inside the rocket, escape through the opening at the rear and send the rocket into the air. This action continues for a time, because the combustion (kŏm-bŭs′chŭn)—or burning—of the powder keeps producing more gas as fast as gas escapes. The process will go on until all the fuel is used up.

The skyrocket, like all other rocket engines, not only carries its own fuel along with it but also supplies its own oxygen (ŏk′sĭ-jĕn) for the burning—for fire must have oxygen in order to burn. The fuel in the rocket usually contains in it some compound that is able to release oxygen—potassium chlorate (pō-tăs′ĭ-ŭm klō′rāt), for example. As the fuel burns, the potassium chlorate supplies the necessary oxygen. Because rockets, for this reason, do not need air in order to



Above is a diagram of a jet-propulsion motor. Air entering the motor is compressed by the impeller, or rotary compressor, and driven into a number of long tubes, or combustion chambers, of which two are shown here. In each chamber an injector constantly sprays in fuel, and a spark plug sets the mixture on fire. The burning gases expand rapidly and their pressure turns the fanlike wheel of the turbine at the rear of the combustion chambers. The turbine is solidly attached to a shaft that has the impeller fastened to its other end, so the impeller turns with the turbine. When they have passed the turbine the hot gases jet out through a narrow nozzle at the rear of the plane. The recoil from this exhaust of gases is what drives the plane ahead.



This diagram of a rocket motor shows how it differs from a jet-propulsion motor. No air enters the motor. Instead, oxygen, carried in the rocket, is supplied to make the fuel burn. As in a jet-propulsion motor, the burning gases rush out at the rear, and the recoil against that exhaust pushes the rocket ahead.

burn their fuel, they operate best in a vacuum (văk'ū-ŭm)—a space from which the air has been removed.

Recently there has been a good deal of experimentation with rockets using liquid fuels. These rockets are amazingly simple in construction. They carry two storage tanks, one containing liquid oxygen, the other gasoline, alcohol, or some other fuel. The fuel and oxygen are led into a combustion chamber within which ignition (ĭg-nĭ'-shŭn)—or burning—takes place. Exhaust gases jetting out to the rear propel the rocket ahead. A pair of rockets, operating in two stages, have already carried instruments 250 miles high. From them we have learned much about the upper atmosphere.

What Is Jet Propulsion?

Jet propulsion is a little different from rocket propulsion. They both work on the same reaction principle. The difference lies in their source of oxygen. A jet-propelled plane, like a rocket, is moved forward by the unequal pressure in its combustion chamber—not, as some think, by the force of escaping gases pushing against the air behind the rocket. But it depends upon the oxygen in the air for the burning rather than upon its own oxygen supply. The jet engine is therefore an "air breather."

A self-contained fuel and oxygen supply —that is, a supply all of which is carried inside the rocket or engine—offers certain advantages, particularly at high altitudes, where the amount of oxygen in the atmosphere is low or entirely lacking. But for flights of average length at lower altitudes, the amount and weight of oxygen necessary for burning the fuel becomes too great to be carried conveniently. Oxygen from the air costs less and is less cumbersome. It is for this reason that jet engines are preferred to rocket engines in present-day planes.

Several types of jet engine have been developed. They differ only in the way in which they "gulp" the necessary air from the atmosphere. The turbo-jet engine is the one most commonly used. In this engine an impeller wheel, like a giant fan, pumps air into a combustion chamber where the compressed air mixes with gasoline forced in under pressure. The mixture is set on fire either by a spark plug arrangement, or—more frequently—by coming in contact with the almost red-hot walls of the chamber. Since the impeller is constantly pressing new air into the chamber from the front, the burning gases expand toward the rear. As the gas moves backward, part of it strikes against another fanlike wheel attached to the shaft on which the impeller rides. This second wheel is called a turbine (tûr'bĭn) wheel. After passing the turbine the exhaust gas puffs out from the rear of the engine, while the engine recoils from the thrust of the jet.

The turbo-jet engine is much simpler and more efficient than the four-stroke-cycle gas engine. There is no elaborate ignition or cooling system in it, and even problems of lubrication disappear. Jet engines running at high speeds yield more than one horsepower for each pound of their weight. They have efficiencies close to 50 per cent as compared with 30 per cent efficiency for the best aircraft engines. That is, nearly 50 per cent of the fuel used is converted into energy to to run the plane. Engineers have even combined the jet engines with a propeller. The turbine turns an ordinary propeller to give the usual thrust, while the jet adds its own thrust to increase the efficiency.

Jet planes can be made to travel faster in level flight than the speed of sound, which is 763 miles an hour at sea level. Just what the speed limit of a jet plane is, must still be determined. One thing is sure, however, that at 1,500 miles an hour, the friction of the air moving over the fuselage of even the most carefully streamlined plane will raise the temperature of the fuselage 400 degrees. Occupants of a plane traveling at that speed within the earth's atmosphere would be roasted alive. And refrigerating units able to counteract that high temperature would be too heavy for the plane to raise them from the ground.

With rocket planes it is a different matter. For since they carry their own oxygen they could mount above the earth's atmosphere. In theory, at least, their speed would then be practically unlimited. The XS-1, a rocket plane of the Air Force, is said to have reached a speed of 1,000 miles an hour.

The STORY *of* FIRE

Reading Unit
No. 1

THE MIGHTIEST SLAVE OF MAN

Note: For basic information not found on this page, consult the general Index, Vol. 15.

For statistical and current facts, consult the Richards Year Book Index.

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Summary Statement

Some unknown Edison, in the shadowy days of long ago, discovered the secret of making fire. But it is only about a century and a half since fire was bidden to make steam and so to turn nearly all the wheels and do nearly all the work of the world. Then it made the world over for us but it still may be very dangerous.

Photos by The National Museum and Union Pacific Ry.

Round and round and round and round between the pa'ms of his hands this Indian had to twirl his stick before the end of it in the hole began to smoulder.

It was a tedious chore, but fire was necessary to the life of the tribe, and someone had to kindle it if it went out. They didn't let it go out often!

The MIGHTIEST SLAVE *of* MAN

How We Have Loaded Nearly All Our Work on the Shoulders of a Servant That We Found Long before History Began

MANY an animal will hover by a dying fire till the last glow has gone out of its ashes and left him shivering in the dark. But never has a single animal dreamed of putting on another stick of wood to keep the fire going.

It is hard to think there ever was a time when man could do no better. We are so used to fire that we may easily suppose our fathers always had it from the very start; and we may even have a little shock when we first learn that fire was one of the things they had to discover.

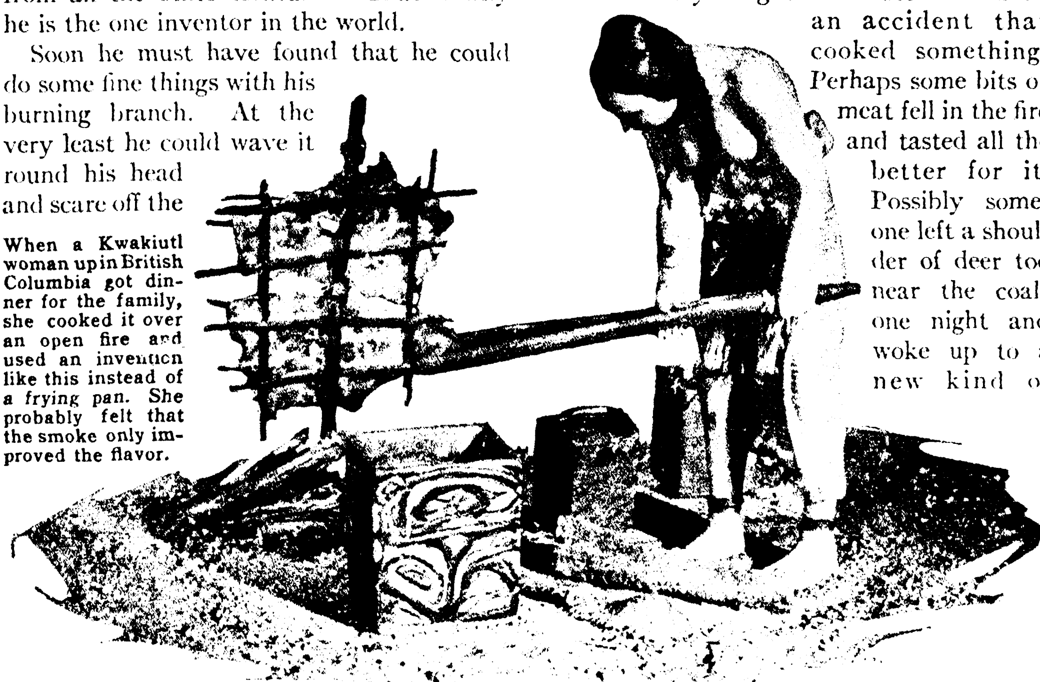
Yet for many a century our fathers had no sort of fire at all. They no more knew how to make a fire and keep it going, or what to use it for, than did a bear or buffalo. If we only think a moment about what their lives must have been like without any fire, and if we remember all that fire has done for us since, we shall see that it is just about the most important of all the discoveries of man.

Of course there had been fires in the world before—from time to time. Once in a while the lightning would set a dead tree aflame, and the rain might be too light to keep a forest fire from following. Here and there the red lava out of a volcano might start a blaze, or a white meteor from the sky might do it. Such fires must have been so rare, however, that few men would ever see

one. And any man who saw one would have run for his life, with all the other creatures in the forest!

But finally some brave man did a thing that no other creature would ever dream of doing. He just picked up a burning branch to look it over. He was curious to see what it was really like, and what he could do with it. In being curious, and in forever asking what he can do with things, man is set apart from all the other creatures. That is why he is the one inventor in the world.

Soon he must have found that he could do some fine things with his burning branch. At the very least he could wave it round his head and scare off the fiercest animals. He could put other branches on it—as he learned in due time—and so keep the fire going as long as he liked. He could place the fire at the mouth of his den and ward off the wild beasts while he and his children slept through the night. And as he lay near the coals he came to know a comfort such as he had never thought to feel in the chilly hours of the dark.



When a Kwakiutl woman up in British Columbia got dinner for the family, she cooked it over an open fire and used an invention like this instead of a frying pan. She probably felt that the smoke only improved the flavor.

Photo by American Museum of Natural History

For these reasons he kept his fire going for some time before he ever thought of cooking. It was not so easy for him to keep a fire burning day and night in rainy weather, and to do all of his hunting at the same time. But it was most important, for if his first fire went out he would have to wait for a meteor or a volcano or a bolt of lightning to make him another; and the chance of any such luck in the next few centuries would be very slight indeed.

But fairly soon many another fire must have been kindled from his first one. Everyone would want a fire when he found out what a good thing it was. And then if his own fire went out, he could start it over again from a neighbor's—if he was on good terms with the neighbor.

Before very long there must have been an accident that cooked something. Perhaps some bits of meat fell in the fire and tasted all the better for it. Possibly someone left a shoulder of deer too near the coals one night and woke up to a new kind of breakfast the next morning. Soon enough, in some way, all men came to love their meat better if it had been scorched. In due time came the clever fellow who simply set all his meat right on the fire and let it burn. He was the first cook.

Even such a clever man still had no way to start a fire. If he already had one, he could light another from it; if not, he would go cold for the rest of his days. It was still many a century before the next inventor found out how to make a fire where none had been before.

Possibly he merely noticed that his two hands grew hot when he rubbed them hard, and thought that two sticks might do the same thing. Possibly he saw two dry limbs

of a tree rubbing together in the wind until they took fire. At any rate, he finally succeeded in rubbing two sticks together so hard, or in twirling one stick in a groove so fast, that the dry wood began to scorch. Such was the first way man ever made a fire. It was the way our Indians used to start a fire, and the way that almost any savage will start one to-day; for there are still a few savages, in some of the Pacific islands, who cannot make a fire, though none at all who do not have fires and know how to use them. Some of the savages who do know how to make fire will travel a long way to borrow it instead, if their own goes out; for it is not so very easy to make a fire with two sticks unless you know just how to do it and have the best materials -as any Boy Scout who knows the trick will tell you.

For many a century we made fires with two sticks, until at last we found another way. It grew common with the use of steel. If we strike a sharp blow with a piece of steel upon a bit of flint, we can make a spark; and if we have some tinder near—some dry shavings or scorched linen—it may catch the spark and start to burn. So for centuries we used to make fire with flint and tinder, as is still the custom in some parts of the world to-day. Only a hundred years ago you would have found flint and tinder on every mantel where you now find matches.

For the first matches fit to use were made only in 1827, by an Englishman named John Walker. They were about three inches long and hard to strike. Soon manufacturers began to use phosphorus (fŏs'fŏr-ŭs) for the match heads- which made them easier to strike. But phosphorus was poisonous and gave the match workers a terrible disease. It was not until 1910 that a phosphorus compound was discovered that eliminated those evils. In the meantime, safety matches the kind that have part of the striking material on the box had been developed, and matches had been improved in other ways.

Waterproof Matches

During World War II when the rainy season of the South Pacific demanded a match that would strike when damp, the match industry produced the waterproof match. By 1943 it was being turned out at the rate of ten million a day and supplied to all the armed forces. All matches are now produced with the aid of machines from logs to finished product and a million and a quarter of them are turned out in an hour.

Imagine so many fires ready to light in an hour - just suppose our poor ancestor with

The paraphernalia below is what our forefathers used instead of a match—and glad enough they were to have it! There are three tinder boxes in the collection—one of them of wood—and the equipment of flints and steels and sulphur matches that went with them. Every tinder box contained a sharp piece of flint and a strip of steel curved round to form a handle, to be held in the left hand. When the sharp edge of the flint was struck against the steel, very tiny bits of the metal were chipped off; and these, red-hot from the force of the blow, fell on the tinder in the box and set it on fire. The person lighting the fire then blew on the tinder—which was usually a piece of charred rag—until it flamed, and then, with much smoke and sputtering, lighted a sulphur match from the tinder. When the lid was put back on the box the fire in the tinder went out. You can judge how long it took to light a fire in this way when you know that people preferred to go half a mile to the nearest neighbor's to borrow a live coal. Sometimes a fire was made from the flint lock on the gun. Powder was put in the pan of the gun, and as the flint in the hammer came down against the piece of metal above the pan, the spark it struck set fire to the powder, which in turn lighted the tinder held near it. One of these old flint locks is shown at the top of the picture.

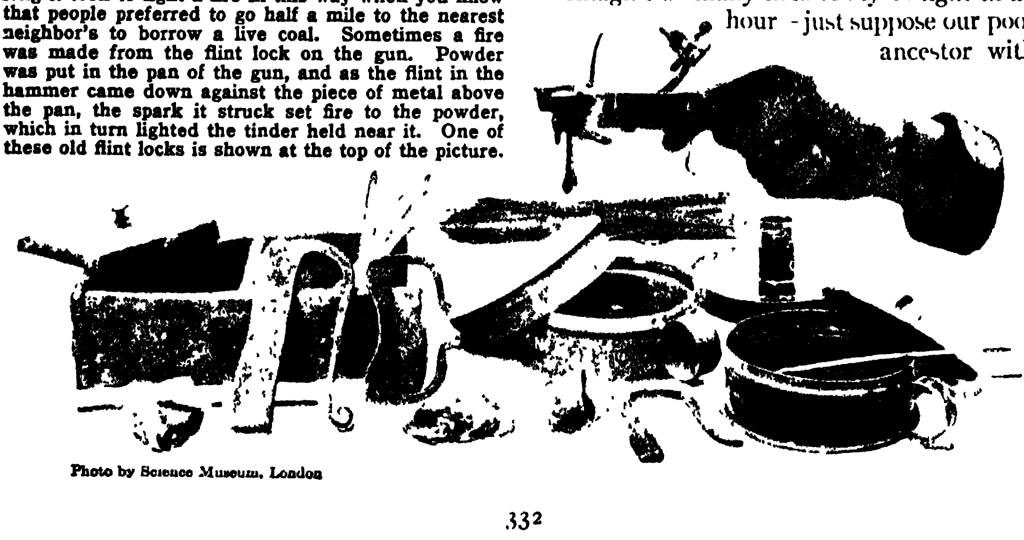


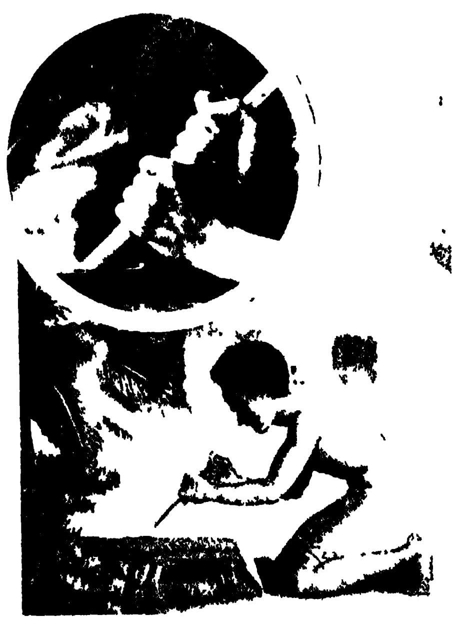
Photo by Science Museum, London

The cave man of the Early Stone Age knew how to twirl a soft stick back and forth in his hands until the point of it, which fitted into a hole, got so hot with the rubbing that it began to smoulder. Suppose it took as long to light each one of the 250 billion matches Americans use every year.

In many parts of the world early men lighted their fires by striking sparks from flint with a stone known as iron pyrites. The discovery must have come about naturally enough, for flint was their favorite material for making arrowheads. When they came to use metals they struck the flint with iron or steel.

Inset photos by James's Press Agency

Anyone with a great deal of patience can light a fire by rubbing two sticks together rapidly until they get hot enough to burn. But you must have soft, inflammable wood, and never stop rubbing for an instant.



If you are very quick and if your arms don't get too tired, you can kindle a fire by rubbing a soft stick back and forth in a groove, as this South Sea Islander is doing. The Indians used the root of a willow.

his two sticks could have known about it! But what runs the machine that makes all the fires? Simply a big fire, of course; for this machine, like nearly all machines, is run by fire itself. And so we make fire with fire, as we make nearly every other thing.

That is what has come at last from being so curious about a blazing branch.

And without fire what should we all be? Savages to this very day. We should have no heat but that of the sun, and no light either. We should have nothing but raw food. We could live only in the hot countries, where the natives are always savage. We could do next to nothing with the metals in the ground. We should have no iron, no brick, no tile, no glass—we should have hardly any of the thousands of things without which we can scarcely think of living. We should still be wild men, and wild men we should stay.

When Men Thought Fire Was God

Now when the wild men of old found anything so important as fire, they were pretty sure to fall down and worship it. It was so precious, and so perilous! That is why our early ancestors nearly always gave a place to fire in their religions, and often a very large place. They made fire into a god, like the sun, and such it remains for many a tribe to this day. Sometimes the form of worship used to be as horrible as anything that wild men ever did. You may read in the Bible of the baleful idol Moloch, in whose red-hot jaws the heathen parents used to put some of their babies to be burned up as a sacrifice to please the god of fire. But oftener the rites were beautiful. An early fire was so precious that the very princesses would have the sacred honor of keeping it from ever going out. So in the grand days of the Roman Empire, the sacred fire in the temple of the goddess Vesta was still guarded by the holy Vestal Virgins, who were the most princely women in the world. And so to this day the Parsees in Bombay guard and worship the sacred fire that they have kept burning ever since they took it with them when they were driven out of their home in Persia thirteen hundred years ago—where it is said to have been kindled by the founder of their faith centuries earlier still.

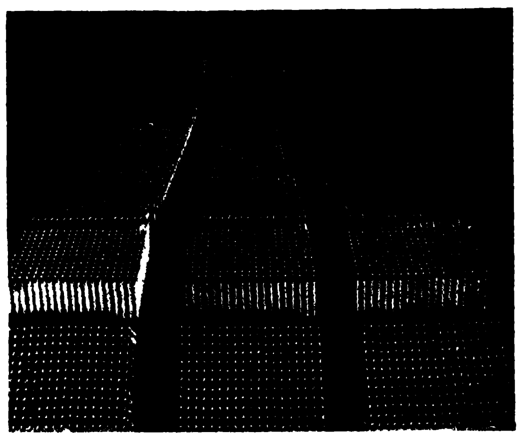
Yet although the men of old knew so much about the value of fire, they had no dream of what fire would be doing for us to-day. It is only about a century and a half since fire was bidden to make steam and so to turn nearly all the wheels and do nearly all the work in the world. Only then did it really do its miracles—or its one great miracle of making the earth over for us. There is no use in trying to tell all the things it does; they would almost sum up our civilization. Every train and steamboat in the world, every motor car and airplane, nearly every piece of the vast network of machinery on which we depend, would stop to-morrow if we lost the secret of fire that some unknown Edison among our savage fathers found out in the shadowy days of long ago.

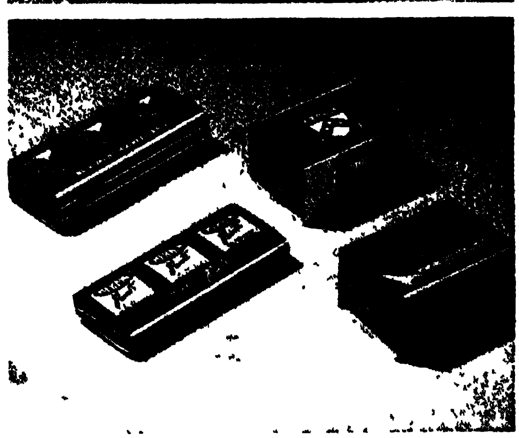
Familiar as we are with fire, fairly few of us know what it really is. There are as many kinds of fire as there are things to burn. For instance, coal is hard to light and then burns very slowly and with very little flame. But a camera film will be afire the moment a flame touches it and will burn very fast and brilliantly. It is called inflammable (ĭn-flăm′ȧ-b'l). Then there are things like gunpowder and gasoline that burn far faster still, for they flare up in a single flash. They are called explosive.

All of these are different kinds of fire, and are used for different purposes. To heat a house all day, or to keep up steam for a long railway trip, we want slow, hot coal. To blast through a rock we want angry dynamite. To drive a motor car or airplane across a continent we want a long series of little explosions of gasoline.

But if the fires in a lump of coal, a stick of dynamite, and a drop of gasoline are so very different, what is there in all of them alike? In a word, what is fire itself? The real answer is that a thing is on fire whenever it starts combining rapidly with the oxygen in the air and giving off heat. It is that combination with oxygen that makes fire.

That is why a flame goes out under a glass. All the oxygen is used up. It is why a match goes out under your foot; you have





Photos courtesy Selvage and Lee

The stick matches which you see neatly boxed in the picture at the bottom right began their lives in the white pine forests of the American Northwest. At the top you see how logs chosen for the match factories are sent down the mountains in man-made water courses, called "flumes," to the rivers which will float them to a saw-mill. There they are cut into blocks and shipped to the match factory. In the factory the blocks are chopped into splints which are carried on an endless chain through dips and drying chambers. At the center of the page you see the beaters which blend the 20 ingredients needed to make the head, and the chain on which millions of matches march to completion. The machine at the bottom left turns out 10,000,000 matches a day.

Photo by U. S. Forest Service

Nowadays fires rarely wipe out whole cities, but a forest fire can trap all the little villages within a given area and reduce them to ruins, with appalling loss of money and life. For that reason an alarm in a forested region during a season of drought calls out every able-bodied man to help in the difficult, tiring work. Here forest officers are fighting a fire in the Wasatch National Forest, in Utah. Watchmen stationed in high towers on top of hills and mountains are constantly on the lookout to give the alarm at the first puff of smoke, and everyone within reach rushes to the spot. Fire lines—wide belts cleared of brush and débris—are often opened in front of the fire to prevent its spreading along the ground.

shut off the air. It is why an electric light is not burning, for the bulb is made airless. It is why the inside of the earth is not afire, however hot, for there is no air inside the earth. And it is why the sun is not aflame, though hotter still; there is no air on the sun either.

We have fire only when a thing combines with oxygen. If the thing cannot do so, it is fireproof—like iron and glass. If it can do so only in part, some of it will always remain—in smoke and ashes.

Any power as strong as fire can always be a demon. Many a time it has got out of hand and done us an evil turn. It burned imperial Rome in the year 64, London in 1666, Chicago in 1871, Tokyo in 1923, and many other towns and cities at other times. When it starts in a great forest it may sweep in mountainous walls of flame over hundreds of square miles, leaving black ruin in the place of the fairest scenes that men may look upon. No one who has never seen a forest fire can dream of the horror of its fury. Nobody who has ever seen one is very likely to be careless in the woods again. For we still have to be cautious to keep our fires in control.

Reading Unit No. 2

WE TWIST, WE STRETCH, AND WE CRISSCROSS

Note: For basic information not found on this page, consult the general Index, Vol. 15.

For statistical and current facts, consult the Richards Year Book Index.

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How did our great-great-grandmothers spin yarn?
How did the "spinning jenny" help weavers?
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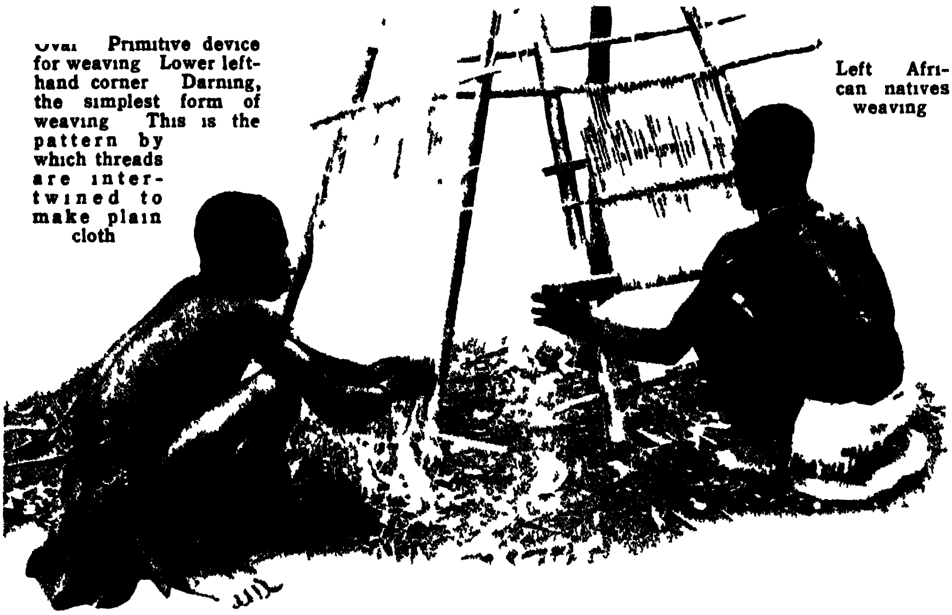
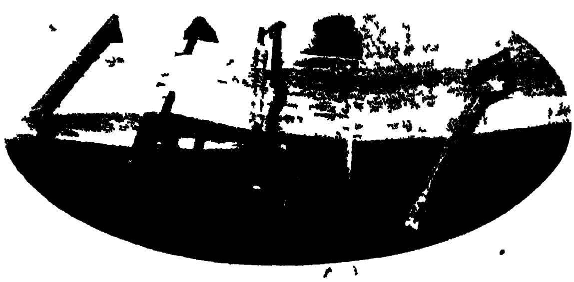
Summary Statement

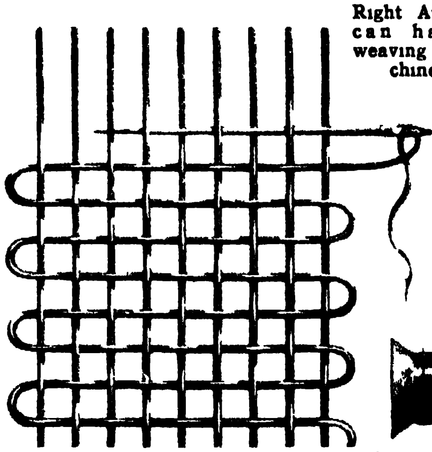
Spinning and weaving are among the oldest of the arts. It was mainly the work of the girls and women to spin and weave the material out of which clothes and other useful articles were made. Modern invention has freed women from the spindle and distaff and loom, and now machinery does most of the work.

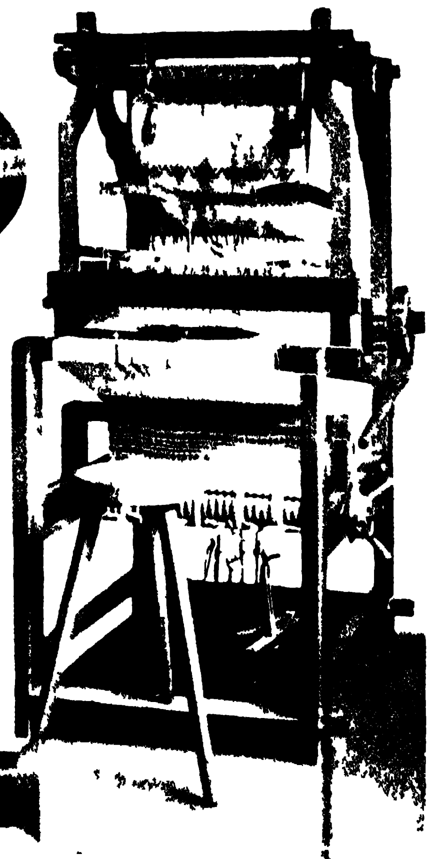
Oval Primitive device for weaving Lower left-hand corner Darning, the simplest form of weaving This is the pattern by which threads are intertwined to make plain cloth



Left African natives weaving







Right American hand-weaving machine

Photos by Field Museum and National Museum

In the days when every stocking had to be knit by hand, little fingers as well as big were set at work turning out the family hosiery. And no moment was ever lost. Women going to market and girls tending the geese kept their needles flying, for in those days it was almost a crime to sit with idle hands.

WE TWIST, WE STRETCH, *and* WE CRISSCROSS

And So We Make Miles of Thread and Yards of Cloth out of the Wool on a Single Sheep

IN THE ancient story of the Sleeping Beauty, the little princess came upon an old woman who was busy spinning. Of course the princess wanted to spin too; but she pricked her finger on the spindle, and so fell into a sleep that lasted a hundred years.

There is extremely little danger that any other little girl will ever have the same bad luck. For what little girl of our day would even know a spindle if she saw one?

But for many a long century, up to very recently, almost every girl had to learn all about spinning, for it was going to be a large part of her work in the world. It is among the oldest of the arts, for we do not know of any people who had not learned it; and it has always been mainly the work of women—so much so that to this day a grown-up girl is sometimes called a "spinster."

So if you had been over in Egypt long before the beginning of history, you would have seen many a girl spinning. And it was very skillful work too; it would be no easy thing for you to learn now.

The art of spinning is simply the art of making fluffy wool—or any other fibrous stuff, like flax or cotton—into a single string, or "yarn." A girl put the wool—which had been "carded," or combed—on the end

of a stick, called a "distaff." Holding this under one arm, she twisted the fibres into a thread and wound them around a spindle.

The spindle was just another stick of wood. It was thin, or "spindling," and pointed at both ends. At one end it had a notch to catch the end of the yarn that was going to wind up on it. It was made to turn round and round. And in the middle it had a sort of disk or wheel heavy enough to make it turn smoothly and evenly. That was all; but it was a pretty clever thing for someone to have thought up centuries before we knew how to read and write. And nothing clev-erer was invented for many a long century afterward

So the girl held her distaff under her left arm and pulled out some twisted fibres to hook on the end of her spindle Then she twirled the spindle and drew out more and more fibres which she twisted or "spun" into yarn as they came. Thus she made one long string out of her fluff; and when she was through, it was all wound up on the spindle ready for the weaver. There are still some savages in the world who make their yarn in this same way.

Photos by Visual Education Service and Metropolitan Museum of Art

This earnest old Italian woman learned as a child the difficult art of spinning with a distaff. Her face tells you how close and exacting the work is. For out of the ball of woolen fluff on the end of the distaff she must twist a long, firm thread. In the oval is a picture of the spindle, on which the thread was wound as it left the worker's fingers.

If you think it sounds easy, you might as well try it if you ever have a chance. It will take a good while to learn, and will make you feel as clumsy as any other thing you ever tried. Yet the little girls before the dawn of history could do it with flying fingers. And they were highly skillful in making their yarn fine and strong and even. Think of spinning a few handfuls of fluff into a thread a hundred miles long!

But they needed all their speed and skill, for every piece of cloth has to begin in threads spun out of fluff. And almost down to our own day the girls and their mothers were making the threads in this same way. There were a few inventions to help them, but our great-great-grandmothers still had to do all the work by hand. Think of the toil –the aching backs, the straining eyes, the tired fingers!

It is strange that in an art so old, and so universal, the improvements came more slowly than in almost any other. Not until about four centuries ago did we have a spinning wheel. This was only a big wheel that made it easier to turn the spindle. It was a great improvement, to be sure, especially after it was made to be turned by a foot, for it left both hands free to handle the yarn And it stayed in use down to the time of our great grandmothers You may still see a spinning wheel in a museum, and sometimes in an old attic

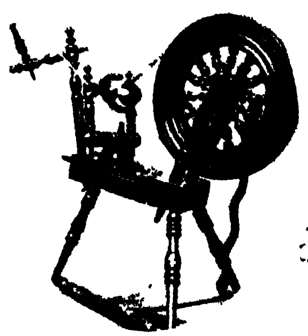
If you had been born in England around 1750, you would have found that spinning was a great business There has always been a great deal of wool in England; and you would have seen whole towns where nearly all the people did nothing but spin and weave, day and night. The people all worked in their own homes, where the women did the spinning and the men often wove the yarn into cloth. So these were called the "cloth towns"

The Sad Fate of an Inventor

In one of them, at Blackburn, lived a carpenter and weaver named James Hargreaves. Through an accident he got the idea of a spinning wheel that would make more than a single thread of yarn at once. By about 1764 he had invented his "spinning jenny," which spun ten threads instead of one.

It was the first great invention in spinning. But the other workmen thought at first that it was going to take away their work, so they broke into the inventor's house and smashed his machine He went off to another town, and tried to patent his invention. But he was cheated by the men he had to deal with, and he soon died, poor and friendless. Meanwhile his machine was coming into use everywhere, and making the fortune of many other men

The spinning wheel, quaint as it seems to us, was a long step in advance over the distaff and spindle, for it wound up the thread that the spinner's fingers had twisted, and it held the distaff, too. The wheel used by our old Dutch peasant woman had to be turned by hand, but the one shown in the oval was operated by a treadle, and so left both hands free to twist the thread. Below is a photograph of models showing how cotton was spun in Japan in the Middle Ages. The Japanese, too, had learned the use of the spinning wheel, though theirs was somewhat different from ours.



Photos by American Museum of Natural History and Science Museum London

A Barber Turns Inventor

The main fault of the spinning jenny was that it would only spin coarse, rough yarn. So Richard Arkwright began dreaming of something better. He was no weaver, but a barber. But he heard the weavers saying that they could not get so much yarn as they needed, and he started out to make a machine that would spin yarn faster.

He spent several years and all his money in the effort. Even his own wife thought he was wasting his time, and once she broke his machine to bits. But he kept right on, and by 1769 he had a patent on his invention. His machine would spin many threads at once, and every thread was strong and fine.

He had better luck than Hargreaves. Two rich men built him a factory, and the business succeeded from the first. So in spite of several lawsuits and many other troubles, the inventor was a millionaire before he died. And he had become Sir Richard Arkwright.

But still a third invention was needed before any machine could spin the finest threads. This was made by Samuel Crompton, and was called a "spinning mule." They might certainly have found prettier names for their machines. But the "mule" worked better than it sounded, for it spun yarn very fine indeed. It succeeded far better than its inventor. Crompton was a poor fellow who worked in a mill and toiled for five years at night to finish his invention. Then he was afraid to show it; and he had plenty of reason, for it was soon taken away from him for almost nothing. Thirty-two years later the British government gave him $25,000.

These were the three great inventions in

spinning, and they all came about the same time. They were the basis for all the inventions that have come since. For of course we have gone on perfecting them until we now have mills with thousands and thousands of spindles, turning out tons of yarn for every pound that came from the old spinning wheel

Above, you may see what the linen in your handkerchief looks like as it comes from Nature's hands. For here is a field of flax, the delicate blue-flowered plant from which linen is made. In the oval is a scene familiar enough in the southern part of the United States when the cotton fields are ripe for picking.

Now when we have plenty of thread, or yarn, how do we make cloth out of it? We have to weave it. And strangely enough, weaving is a simpler thing, at least in its early forms, than spinning It is easier to make our threads into a piece of cloth than it was to make the threads in the first place. So people knew how to weave even before they had learned to spin. For they had plenty of things that could be woven; we still weave some kind of grass, for instance, whenever we make a straw hat.

How We Weave a Piece of Cloth

All we need to do in simple weaving is to lace our threads together, in crisscross fashion, over and under one another, just the way we string a tennis racket or make a cane seat. The result is cloth, and we can make it the first time we try; though to make it fine and beautiful we need a great deal of experience.

First we may string out hundreds of threads all running the same way, and as close as possible together The closer they are the stronger our cloth will be. All these threads together are called the "warp" Then we may take another thread and run it straight across and through the threads of the warp—over the first one, under the second, over the third, under the fourth, and so on to the last Here we double back and run it through the threads again to the side where we first started, and so we go on back and forth until we have woven our cloth. All the threads running across and through the warp are called the "weft" or "woof" Of course the closer we can get them together the stronger our cloth will be. And all this our forefathers knew long before the dawn of history.

Below at the right you may see any number of woolen stockings and caps and sweaters, but all unspun. For we must rob the sheep of his coat to get our wool, and then the soft fluff we shear from him must go through any number of processes before we can put it on as a dress or coat to keep out the cold.

Photos by U S Dept of Agriculture Nature Magazine and J C Allen

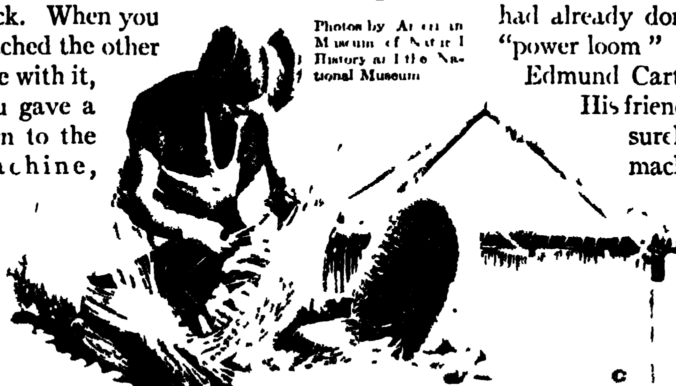
The Invention of the Loom

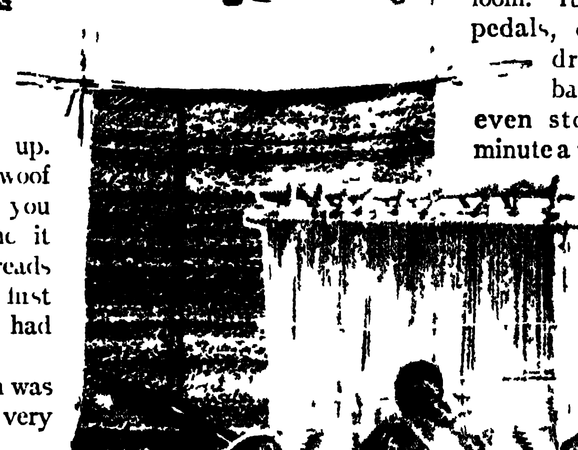
But it was weary work. Just imagine running a thread back and forth thousands of times, pushing it under and over, under and over! By the time of the Egyptians, there was a machine that helped a great deal in the work. It was a "loom." The

first loom merely lowered every other thread of the warp, and lifted every thread in between; so there was a space between the threads of the warp, and one simply ran the thread of woof through the space, without having to lift it up and down all the time. The thread of woof was run through on a stick. When you reached the other side with it, you gave a turn to the machine, and every thread of warp that had been up went down, while those that had been down came up. Then you ran the woof thread back to where you started, and this time it went under all the threads it had gone over the first time, and over all it had gone under.

In due time the loom was improved, but very, very slowly. Until less than two centuries ago it was always run by hand. The weaver would open the space between the warp threads by pressing on a pedal. Then the woof thread would be carried through on a shuttle. The shuttle was a little wooden case with a spool of yarn inside; and as it passed through it unrolled the thread of woof behind it. Thus it would travel back and forth day after day. And that is about the way all cloth was made until a century and a half ago.

Photos by American Museum of Natural History and the National Museum





Many savage tribes are skillful weavers, though of course they have to do all the work by hand. Our own American Indians make some very beautiful things. At the top is a Hopi Indian woman weaving baskets. The center picture shows a loom of the Zuni Indians, with a blanket partly finished on it. And at the bottom are Pueblo Indians at work on one of the blankets whose patterns we have learned to know so well.

At last there came a time when the spinners got far ahead of the weavers. They had found machines that would turn out yarn much faster than the weavers could make it into cloth. So the next thing had to be a loom that would work far faster; and it needed steam to run it, for the human hand had already done its best. It had to be a "power loom."

Edmund Cartwright started to invent it. His friends only laughed at him, for he surely had learned nothing about machinery in his college at Oxford, and since then he had been an English clergyman. But he kept on as best he could, and by 1785 had made the first power loom. It would press the pedals, open the warp, drive the shuttle back and forth, and even stop working the minute a thread broke! For the yarn of the woof was made to run over a little fork, and if the yarn broke, the fork would slip back and shut off the power.

Cartwright made many improvements on his first machine, but he never prospered from his own invention. He had a good deal of trouble with the weavers who thought his new loom would take away

Photo by the Corporation of Manchester

The first great modern invention in weaving came in 1733, when John Kay, an Englishman, devised the fly shuttle, without which our great power looms could never have been invented. But the weavers did not welcome the labor-saving device. They thought it would take their work away. So in 1753 rioters stormed Kay's house, and the inventor's life was saved only by the quick-witted plan of his wife, who had him wrapped in a sheet and hurried out of the house in the arms of two workmen. The picture shows Kay's wife and daughters, his son on guard, and his loom, with the fly shuttle on the floor beside it.

their work. When he had a factory of four hundred looms about ready to start, someone set fire to it and burned it to the ground At the age of sixty-six, Cartwright finally received $50,000 from the government, but he had spent about four times as much in perfecting his machine

Wonders of a Modern Loom

Of course the machine was soon a huge success Since that day many inventors have gone on perfecting it—making it stronger and stronger, cleverer and cleverer To-day we have great looms that pull and stretch the cloth exactly as they should, keep all the threads just tight enough, fill the shuttles when the spool inside is empty, roll up the new cloth at just the right speed, and still need so little help that a single weaver has been known to run a hundred looms. Just remember how all this had to be done in Egypt!

How We Make a Carpet

There are so many special kinds of weaving that we have no time to tell about them all. Many of them are hardly known to anyone except a weaver

When you look at a piece of plush, for instance, or a carpet, it certainly does not seem to be a mere set of threads, half of them running one way and half of them the other It is all velvety with what we call the "pile," and no sort of thread can be seen at all But underneath the pile is the woven cloth, and it is only tufts of silk or wool tied into this and sticking up out of it that have been cut off smooth to form the pile

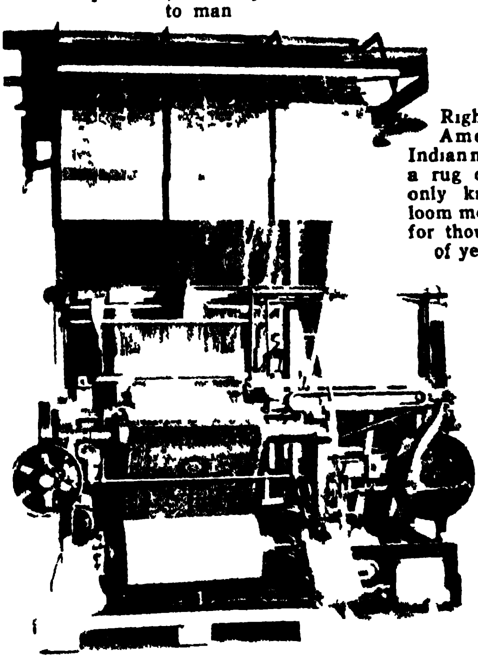
The most wonderful of all weaving machines is the one that puts the patterns into cloth Everybody knows the marvelous patterns of color that appear in shawls and dresses, in curtains and in rugs How can we weave pictures of birds and flowers into cloth if we have nothing but a thread to go over and under, across and back?

How Designs Are Woven in Color

Well, it is a complicated business, but there is a machine that does it all without stopping to think. The machine will pick out any number of colored threads you want, and bring them into view on top of the cloth exactly where you want them. Of course the woof thread in the shuttles has to be changed every so often. So when a new color is needed, to begin a new part of the pattern, the machine stops; then it actually

Here are some of the steps in weaving a rug First, an artist must make the design and paint in the colors on cross-section paper, as shown at the extreme left. Then a machine must stamp the design on cardboard, with thousands of little perforations

When the design of the rug has been stamped into the cardboard pattern, that pattern is duplicated over and over on long laced sheets in the machine shown at the right These perforated sheets, which look much like the rolls of paper in a mechanical piano, are what control the pattern in a Jacquard loom, like the one shown below As they run through the loom the rug is woven, according to their perforated patterns, in every color known to man



Right An American Indian making a rug on the only kind of loom men had for thousands of years

Photos by M l awk Carpet Mills u l Tucs i S rsl ne Cl b

Photo by Kentucky Progress Commission

This was the home of the men and women who pushed the frontier westward. The picture comes from Harrodsville, Kentucky, the land of Daniel Boone. Here the wool was carded, spun, dyed, woven, and made into clothing, while the lonely worker kept an eye on the peephole in fear of an Indian attack.

lifts a string to show the weaver what color is needed next.

We have all seen the rolls of paper that are used in mechanical pianos. They are punched full of different kinds of holes, and each hole plays its own kind of note. The weaving machine uses cards punched in the same way, and the cards make the machine do all its different duties in weaving the complicated pattern.

It took nearly a hundred years to invent this great machine, and many different people had a share in its making. It was at last perfected in 1801 by a Frenchman named Jacquard (zhä'kär'), and it is named after him. Jacquard started as a poor workman in a silk mill at Lyons, but he was more fortunate with his invention than some of his English brethren. For when he came up to Paris with his machine, the government took over the idea, gave him a pension, and forced every mill that used his loom to make him an annual payment. In a little while the land was full of Jacquard looms, and the inventor was a rich man, as he so well deserved to be.

In all these ways we have spun and woven many kinds of stuff wool and cotton, silk and flax and jute. The main idea has always been the same to twist and stretch the fibres into yarn, and then to crisscross them into cloth.

But in the past few years we have found a brand-new way of spinning—though it is one that the spiders have known all along. The spider spins a thread by squeezing a liquid through a very small hole. And that is just the way we now make artificial silk, or rayon. About rayon we are telling in another story, but we ought to say here that the very latest triumph in our spinning was the secret of the spider long ago.

Reading Unit
No. 3

FROM BOW AND ARROW TO ROCKET GUN

Note: For basic information not found on this page, consult the general Index, Vol. 15.

For statistical and current facts, consult the Richards Year Book Index.

Interesting Facts Explained

Things to Think About

What horrors may the next war bring?
Why are modern wars exceedingly terrible?
For what reasons did ancient man make weapons?
How much does a single battle ship cost?

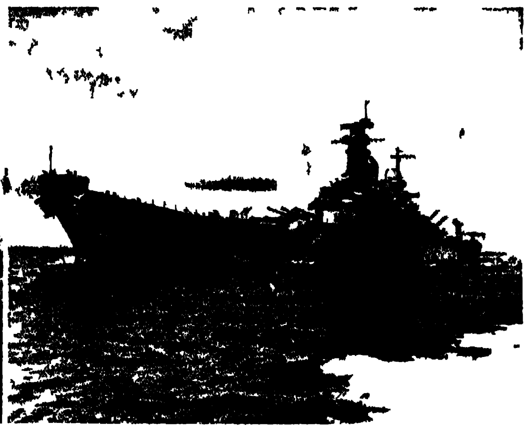
Picture Hunt

Related Material

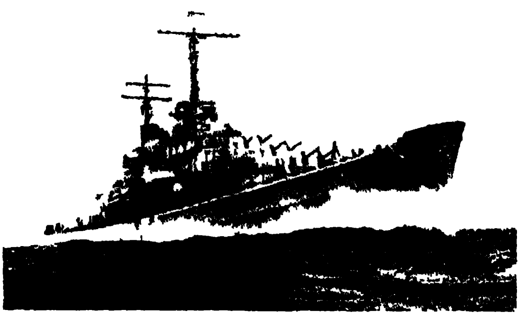
Summary Statement

The story of how we have learned to wound and kill since the day when the first man threw a stone at some beast or some other man is one of clever invention. It is also about the saddest story in the world. Everybody suffers in modern warfare, and there is a real fear that if we cannot keep the peace, our whole civilization may be brought to utter ruin.

The U S S "Franklin D Roosevelt," an aircraft carrier, relies on her planes to carry the fight to the enemy

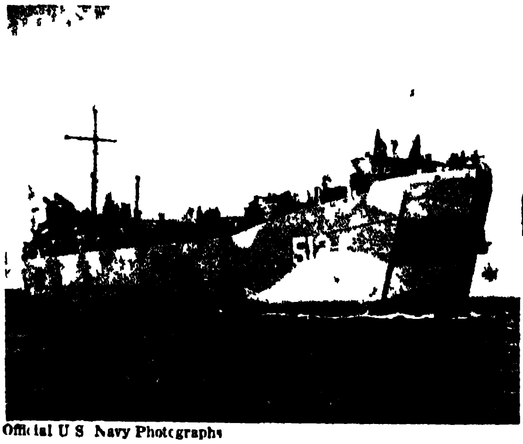


Battleships like the U S S "Missouri" can devastate fleets and shore batteries with their mighty guns



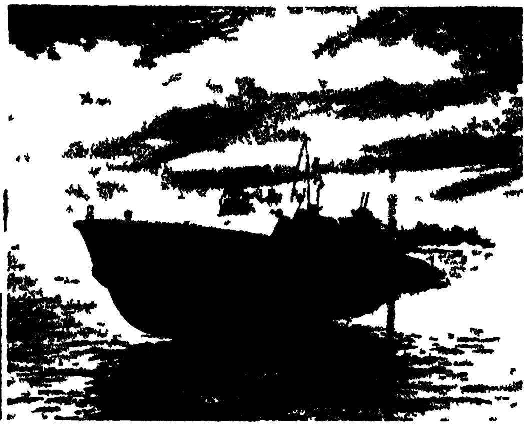
Heavily armed against any air attack, light cruisers can inflict heavy damage on both ships and airplanes

A menace to any opponent on shore on the sea, or beneath the sea. is the swift and powerful destroyer



Official U S Navy Photographs

The LST, with its cargo of men and weapons, carries the force of amphibious warfare to hostile beaches



The fastest of naval vessels is the PT boat, which is built for "hit and run" torpedo raids on the enemy

Photo by American Museum of Natural History

Man and a very few other animals, such as the apes which have learned to hurl things at their enemies, are the only creatures who use any weapons except the ones that Nature provided. Even the king of beasts, in spite of his deadly claws and rending teeth, must yield to these lion hunters, who, no matter how primitive, have better weapons than any that Nature could have given them.

From BOW *and* ARROW *to* ROCKET GUN

This Is the Tale of All the Things That Man Has Made to Fight with Since the Day When He Wielded the First Club

EVEN before the first men learned to talk, they must have known how to fight. Strange and terrible beasts stalked round them, and other human creatures as wild and savage as themselves might fall upon them at any moment, to dispute with them a meaty bone or a warm cave shelter. In the law of the jungle, might is right.

But nature had not given them any very good weapons for fighting. They had no horns on their heads to gore their enemies, as had the rhinoceros; they had no long, sharp claws or tremendous teeth, as had the terrible saber-toothed tiger; they had no bony armor to protect their bodies, as had the ancient reptiles. Often they must have run away, or climbed tall trees to safety, or crept into narrow caves where their enemies might not follow.

It was their wits and the skill of their hands that saved them. They learned how to fling

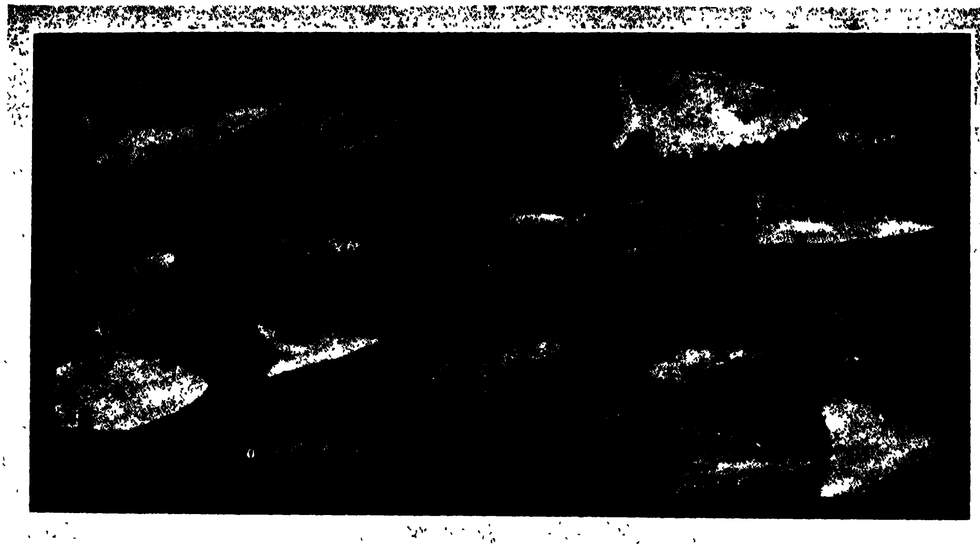
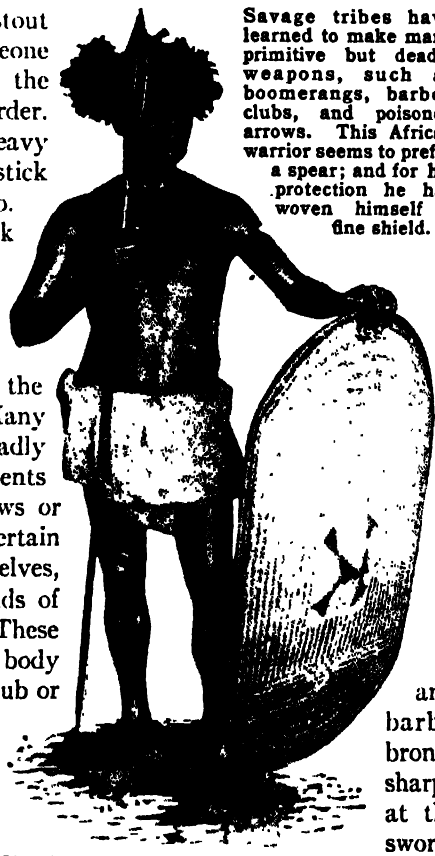


Photo by American Museum of Natural History

Even to-day, in the woods or in a field where not so very long ago there stood a stately forest, you may find one of these arrowheads that the Indians used in hunting. The poet Longfellow must have been thinking of these carefully chipped and sharpened stones when he described how Iagoo, the friend of old Nokomis, cut an oak bough and out of it made arrows for Hiawatha, "tipped with flint, and winged with feathers."

stones and to swing a stout stick as a club. Then someone made a sling to throw the stones farther and harder. Someone else tied a heavy stone in the split end of a stick to make a more deadly club. Sharp pieces of hard rock became knives. Bits of pointed rock or bone tied to the ends of poles became spears. In time, some great genius made the first bow and arrow. Many tribes learned to gather deadly poison from plants or serpents and tip the ends of arrows or throwing sticks with certain death. To protect themselves, they began to make shields of wood or hide or basketry. These could be held before the body with one hand while the club or spear was launched with the other; some savage tribes even have small shields which can be hung about the neck or shoulder, leaving both hands free to bend a bow. All these primitive weapons, in all sorts of queer forms, are still used in certain parts of the world to-day.



Savage tribes have learned to make many primitive but deadly weapons, such as boomerangs, barbed clubs, and poisoned arrows. This African warrior seems to prefer a spear; and for his protection he has woven himself a fine shield.

Photo by American Museum of Natural History

But in other parts of the world, very different weapons were already being made as much as four thousand years ago. For men had begun to know the use of metals: the Stone Age was passing into the Age of Bronze. If you will read our story about bronze, you will find many curious and interesting facts about what the ancient peoples—the Egyptians and the Cretans, the Greeks and Romans and northern barbarians—did with their bronze. They made strong, sharp spears and lances to throw at their enemies, daggers and swords to thrust and slash, axes and maces to crush and hack.

In the days of ancient Rome, slaves and criminals were often chained, in the manner shown above, to the "galleys," or warships, and were forced under the lash to row sometimes until they died from sheer exhaustion. If the boat were sunk, these miserable creatures went down with it, chained to the oars. This was a common punishment for criminals as late as the eighteenth century; and in Spain to-day the name "galera"—or "galley slave" is still used for a criminal, a grim reminder of the past.

They rimmed and studded their shields with metal to make them stronger, or made them out of bronze altogether. They protected their heads with bronze helmets, their bodies with cuirasses (kwē-răs′), their legs with greaves (grev)

In those old days, when a man's business was largely fighting, his weapons and his armor were often the richest and most beautiful things he had. Savage tribes decorate their bone knives and their wooden lances. Bronze Age warriors delighted in jeweled daggers, inlaid swords, and shields with raised designs. How gorgeously armed were Homer's heroes as they went forth to battle! Do you remember the description of Achilles' shield, which was forged for him by Vulcan himself, the smith of the gods?

The Greek warriors who fought at Marathon were not very differently armed. The Romans tried to make the armor lighter, and used more iron and less bronze. For in some parts of the world men had begun to know how to use iron more than a thousand years before Christ.

From the time when men first went down to the sea in ships, they have carried their quarrels to sea with them and fought upon the water. The most famous of all the ancient war vessels were the Roman galleys, which won the Mediterranean from Carthage and held it against the world. These were

wooden vessels, not very large, fitted with sails but usually propelled by oars. The common warship was called a trireme (trī'rēm) because it had three banks of oars. To each oar was chained a rower—some unhappy prisoner of war, perhaps, or some criminal sent to the galleys for his crime. Rhythmically the long rows of galley slaves would lift and drop the oars, sending the ship swiftly through the water on its deadly errand.

Above in the sunshine stood the soldiers. When a battle began, one boat would try to sink the other with the pointed ram that it carried at its prow. Upright by the mast was a huge beam of wood with hooks in the end; when an enemy ship came near enough, the crew let this beam fall across the decks to fasten the boats together. Then the soldiers tried to board the enemy vessel, fighting hand to hand with swords and axes.

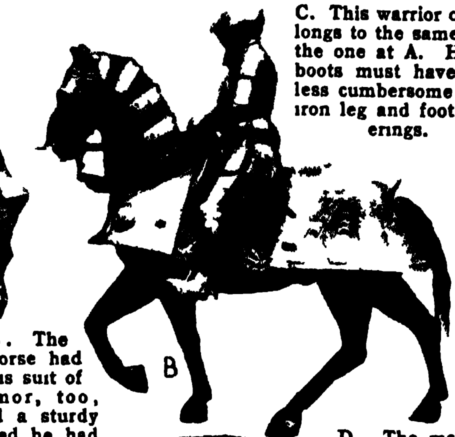
Except for the vikings, those hardy sea kings of the north, the people of the Middle Ages did most of their fighting on the land. And the knight of that day thought a great deal about arms and armor. No one was much more important to him than his armorer. Because he spent so much of his time in fighting, the knight went more and more stoutly clad in "iron clothing." At first it was rare and costly. The emperor Charlemagne (shär'lē-mān) made laws against selling any "byrnie" out of the country; a byrnie (bûr'nĭ) is a shirt of mail made of leather or cloth, with iron disks or rings sewed on it. He gave orders that every landed noble must have a byrnie of his own, and should lose his land if he appeared for battle without it. But even to the end, the finest armor was only for the wealthy. The common foot soldiers wore little more than helmets and breastplates. For if you are going to dress up in iron you will not be free enough to march and charge with the infantry - you will have to join the cavalry instead.

The armor of the Greeks, like everything else made by that beauty-loving race, was well made and beautifully ornamented. An imposing triple-crested helmet was not uncommon. Some helmets were adorned with plumes or feathers and had cheek plates; others covered the whole face, leaving only slits for the eyes. Besides the helmet, the Greeks wore breast and back plates and greaves of pliant bronze to protect their legs. They carried long graceful spears, short swords, and small round or oval shields decorated with beautiful pictures of animals or fanciful designs. To the left is a Greek warrior.

The Roman soldier was armed according to his rank and according to the period in which he lived. At the right is a soldier of the Roman legion. He wears a heavy corselet and a helmet with protecting cheek plates, and he carries a large rectangular shield. Besides the short sword, these soldiers often fought with a stout javelin; but in the days of the empire the heavy-armed infantry usually carried the long sword and the dagger.

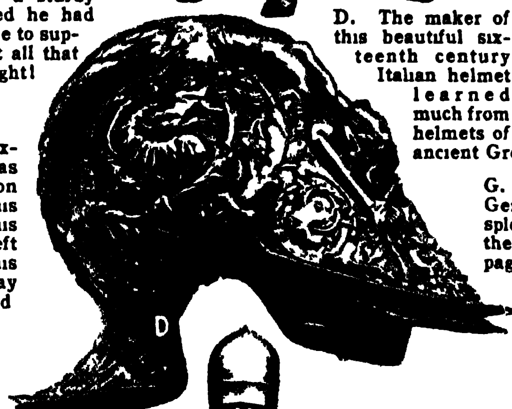
So most of the knights fought on horseback. Little by little the armor came to cover the knight's whole body, and finally most of the horse's body too. At the time of the crusades (krōō-sād'), those wars fought for the possession of the Holy Land, our knight rode forth in a robe of chain mail fitted over quilted garments of cloth. Chain mail is made of interwoven iron rings. These suits were so hard to get into and out of that the crusaders must have spent days in them at a time, and they were so heavy and cumbersome that people are still wondering how the warriors ever lifted their great swords against their enemies. Later, our knight would wear, not chain mail, but plate armor, solid plates of metal jointed and fitted to cover and protect him. Plate armor will protect you better from a lance thrust than will mail, but it is still stiffer and heavier. Often enough a knight, unhorsed and rolled in the dust, could not get up to his feet for the life of him, though he might not have a single wound. He simply could not manage it in his armor! One cannot help thinking of the huge armored beetles that, once turned on their

A This knight of sixteenth century Italy was more heavily armed on his left side than on his right, for of course his right arm must be left free for fighting. This type of armor did away with the need for a shield

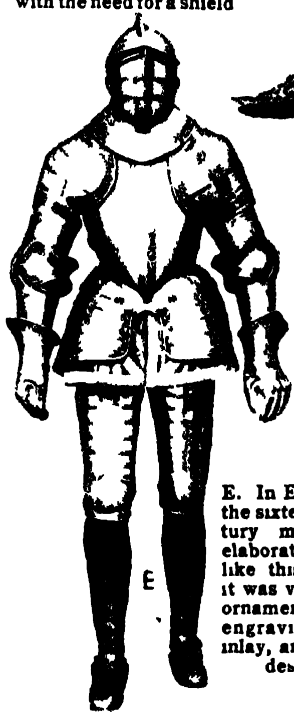


B. The horse had his suit of armor, too, and a sturdy steed he had to be to support all that weight!

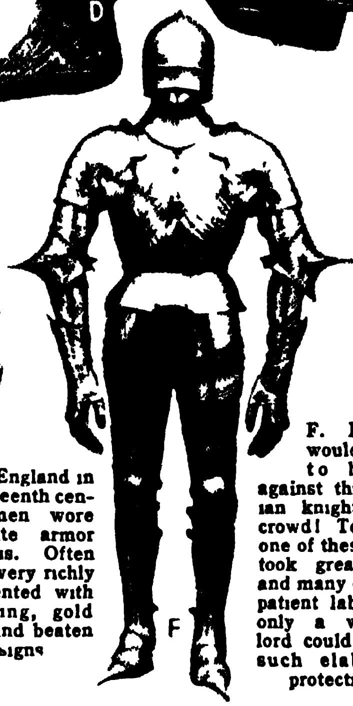
C. This warrior of Italy belongs to the same period as the one at A. His leather boots must have been far less cumbersome than iron leg and foot coverings.



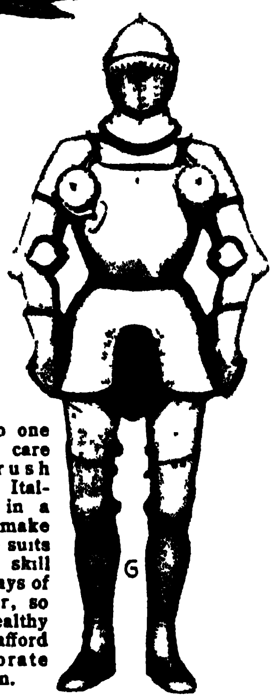
D. The maker of this beautiful sixteenth century Italian helmet learned much from helmets of ancient Greece



E. In England in the sixteenth century men wore elaborate armor like this. Often it was very richly ornamented with engraving, gold inlay, and beaten designs



F. No one would care to brush against this Italian knight in a crowd! To make one of these suits took great skill and many days of patient labor, so only a wealthy lord could afford such elaborate protection.



G. The armor of this German knight is not so splendid as are some of the glittering suits on this page, but it served its purpose of protection just the same.

Photo by Metropolitan Museum of Art

Photo by [illegible]

Every age has its favorite pastime. The Greeks held athletic contests in honor of their gods. In Rome the mob swarmed to the amphitheater to see the cruel combats between gladiators. All the color and romance of the Middle Ages is shown in the tournaments, where the nobles fought sham battles, one against another or in groups. Thus they won favor in the eyes of their ladies and fame in the eyes of the world. Champions from far and wide assembled to show their prowess, proud damsels of the court looked on from the galleries, and bold heralds shouted the rules of the tourney and the order of events. But even this romantic scene of flashing armor and bright banners had its unpleasant side. The play was rough, and many a noble knight was thrust from his horse never to rise again – or to leave the lists a cripple for life.

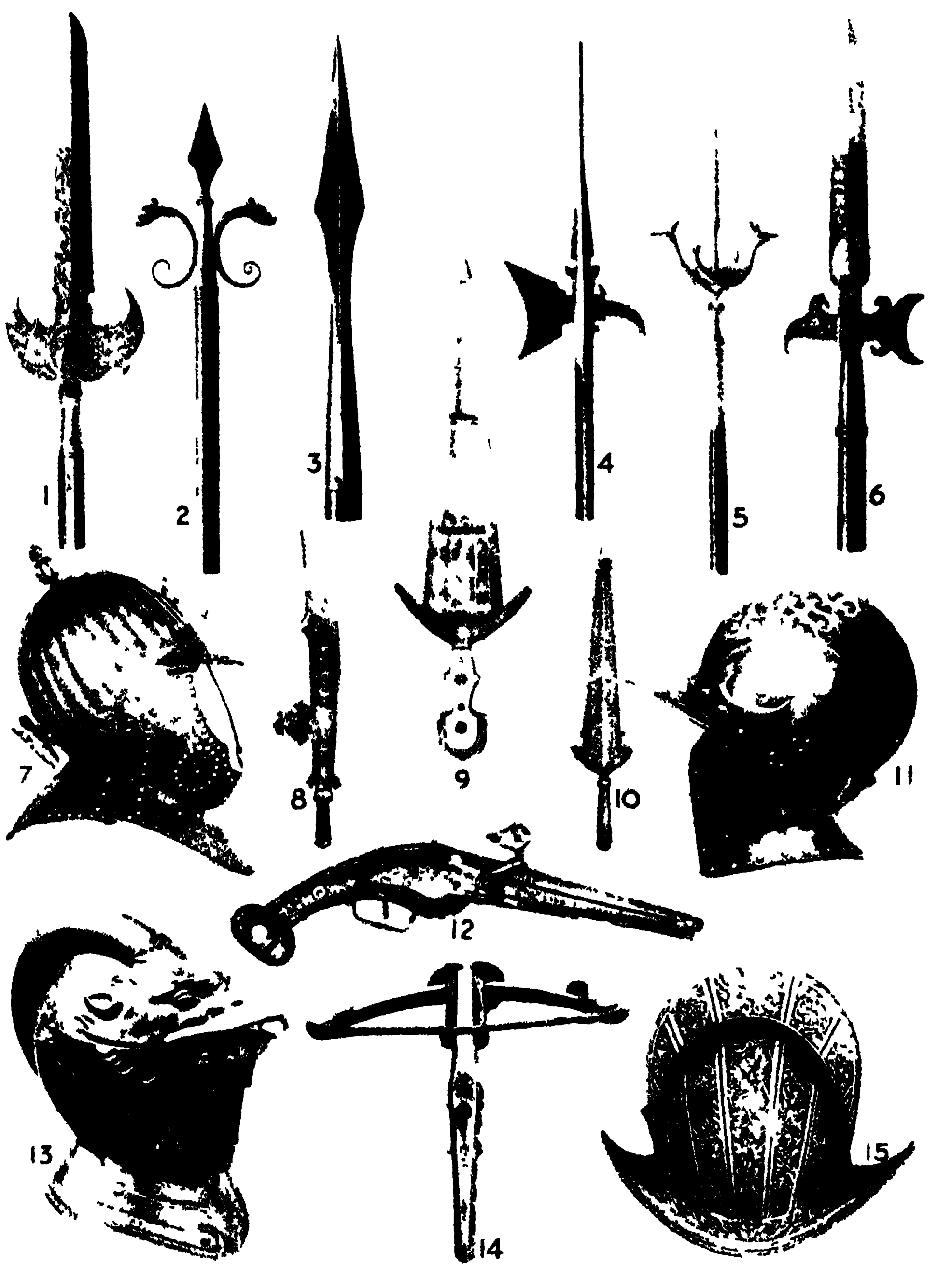
back, have such a hard time to get up again

War in the Middle Ages was brutal enough, but it had its glitter and splendor too. How proud the knight was of his prancing, armored steed, of his own firm seat in the saddle, erect in his shining coat of metal! With iron gauntlets on his hands and iron shoes on his feet, with the vizor of his helmet closed down over his face and all the rest of him completely covered with iron or steel, he couched his long slim lance in rest. A gay plume nodded over his head, and perhaps a glove or a crimson sleeve given him by his beloved lady. His coat of arms, the emblem of his honorable name, was emblazoned on his shield or worked upon a light garment worn over his shield. His armor was often richly decorated In the later Middle Ages some of the knights were so vain of their iron clothes that they had them made in iron puffs and folds, to look like the fashionable cloth robes In one style there were steel shoes with upturned toes so long and flourishing that they had to be screwed on after the owner had mounted his horse!

Photo by Metropolitan Museum of Art

Here is one of the coats of chain mail worn by the soldiers of the sixteenth century.

All this war gear, of course, was for use in single combat, hand to hand Sometimes the fight would be merely for pastime, as in jousts or tourneys (tûr′nĭ), where the champions met to show their prowess before the king and the ladies Sometimes it was a chance encounter in some lonely wood. Sometimes it was a pitched battle between



Photos by Metropolitan Museum of Art

The beauty of a modern weapon lies in the fact that its shape is adapted entirely to its purpose. But in olden times weapons were prized for their artistry as well as for their usefulness. To learn to wield them gracefully, as well as with deadly precision, was part of the training of a gentleman. Above are: No. 1. Austrian seventeenth century spear. Nos. 2, 4, and 5. German seventeenth century halberts. Nos. 3 and 6. French seventeenth century halberts. No. 7. Helmet worn in France in the eighteenth century. No. 8. Italian seventeenth century weapon. Nos. 9 and 13. Italian sixteenth century weapon and helmet. No. 10. Sixteenth century Dutch spear. Nos. 11 and 14. Saxon sixteenth century helmet and fourteenth century cross-bow. No. 12. French sixteenth century pistol. No. 15. Spanish sixteenth century helmet.

This painting from the Panthéon in Paris is one of a series which tells the story of Joan of Arc. It shows the capture of the saint by the English. You will notice that the fearless girl is wearing the heavy armor of a knight, while the common soldiers attacking her are protected by chain mail.

nobles or nations, with longbowmen and other infantry to back up the knights. Often there was a walled city or a castle to be stormed and taken—or defended.

Ever since ancient times there had been special weapons for the storming of fortified towns There were battering-rams, huge logs of wood tipped with iron, which could be swung against gates or walls by many men working together. These often crashed holes in the masonry through which the warriors could climb. There were catapults (kăt′-à-pŭlt), or machines for throwing large stones over a wall. There were siege towers, which could be rolled up to the wall so that the besiegers could attack the ramparts from them.

But just as the medieval knight learned to cover himself so well with armor that it was almost impossible to kill him, so he made his home stronger and stronger, until it was next to impossible to capture it He built huge stone castles with walls and battlements and massive ramparts, and around them he dug a deep, wide moat, which he filled with water The only way of crossing this moat was by a bridge, which he drew up after him Many of these castles are still scattered over Europe to-day. When you journey up the Rhine, for instance, you will see some of them, in magnificent ruin, frowning down on the river from craggy hilltops. Others, like Warwick (wŏr′ĭk) and Windsor in England, are still used as residences

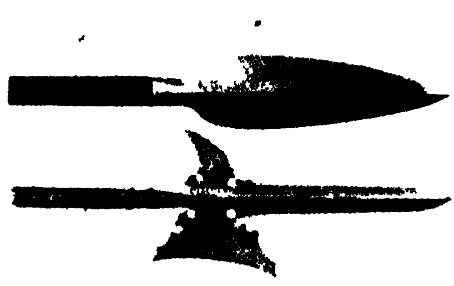


Photo by Metropolitan Museum of Art

In this picture you see a sixteenth century German halbert, or combination axe and spear; it was used by soldiers on foot to attack their mounted enemies. With it is the plain sharp blade of a fifteenth century boar spear.

Men might, perhaps, have gone on to this day living in stone castles and riding about incased in steel if it had not been for the

Photo by the National Museum

When the Romans besieged a citadel they might use a siege tower (1), a battering-ram (2); a "testudo," or shelter of shields (3); and a catapult (4) or a ballista (5) to hurl spears, arrows, or heavy stones.

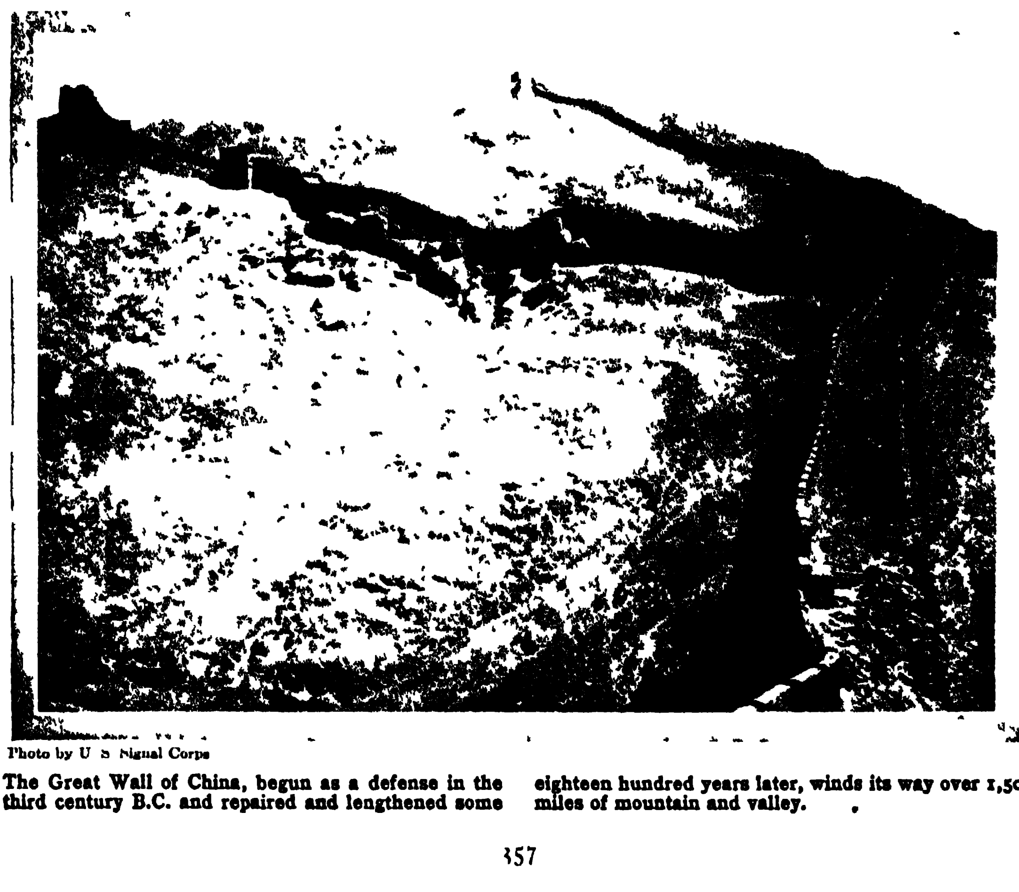


Photo by U S Signal Corps

The Great Wall of China, begun as a defense in the third century B.C. and repaired and lengthened some eighteen hundred years later, winds its way over 1,500 miles of mountain and valley.

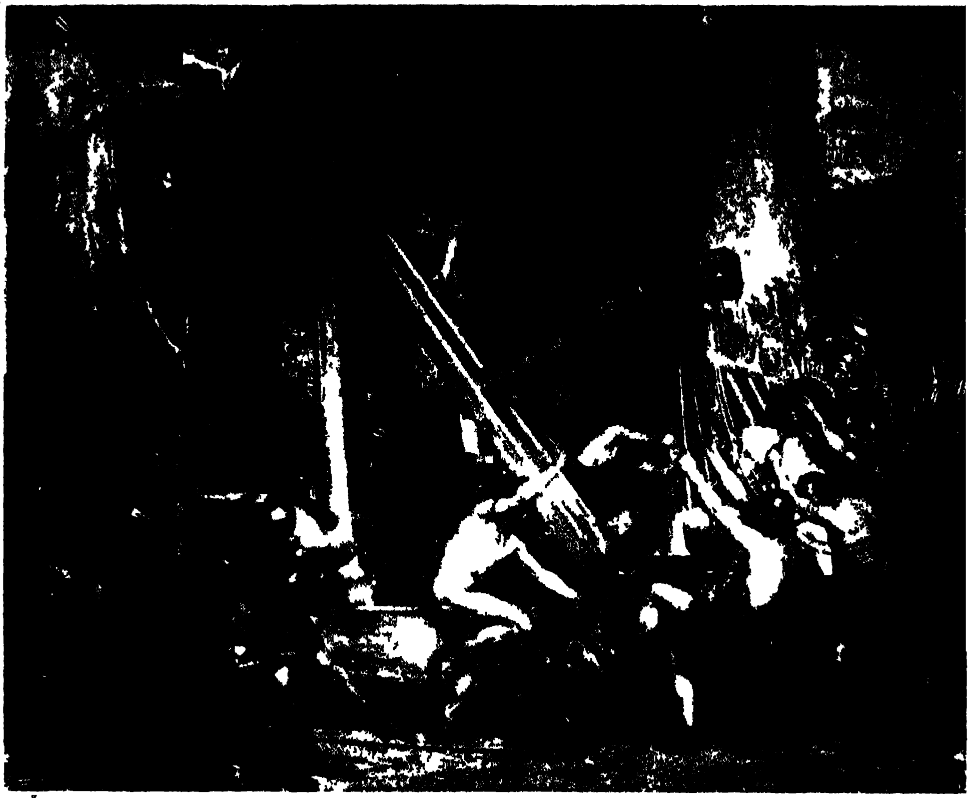


Photo by the Autotype Fine Art Co.

For people who had not yet learned the use of gunpowder, the catapult was a mighty weapon. In the warfare of the Romans it was used for the same purpose as our cannon, and hurled stones with great force into the ramparts of the enemy. Above you see the soldiers pulling the great arm into position for shooting.

invention of gunpowder. But castle walls that were proof against the stoutest battering ram could not stand before cannon, and a steel-clad horseman could be bowled over like a tenpin by a single shot For centuries after the first guns were made, the armorers kept on trying to make armor proof against them. But slowly they lost the hopeless contest, though a certain amount of armor was still worn as late as the time of Cromwell, in seventeenth century England

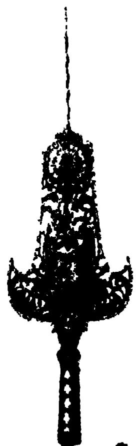
The Invention of the Cannon

Cannon began to come into use here and there early in the fourteenth century The ancient Greeks, the Arabs, and the Chinese had had machines for throwing fire. But gunpowder in a metal gun could throw stones or lead or iron balls fiercely and far Of course it was by no means so far as a modern cannon shoots, a gun that could toss its shot five hundred feet was a mighty weapon in those early days, while a modern big gun can easily shoot twenty miles or more. But the early cannon was deadly, just the same It was made of wrought iron or bronze, and was often beautifully ornamented

A New Age for Navies

In fighting on the sea gunpowder made just as great a change Only once in a while did warships now grapple to fight hand to hand Usually they fought with their guns The great thing was to be clever enough at sailing to cross the bow or stern of the enemy vessel and let fly a broadside while the enemy, being end on to your ship, could not fire back Common soldiers almost vanished from warships, and skillful cannoneers took their place


1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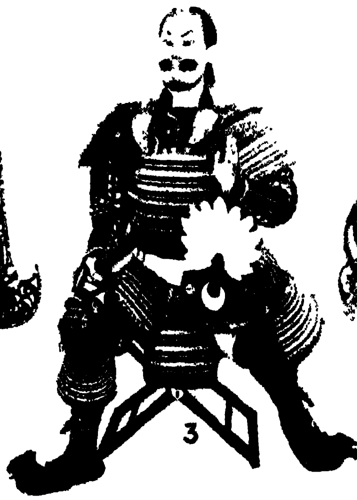
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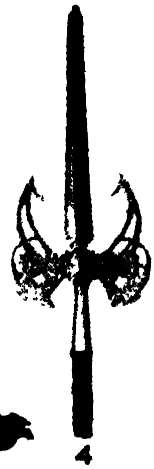
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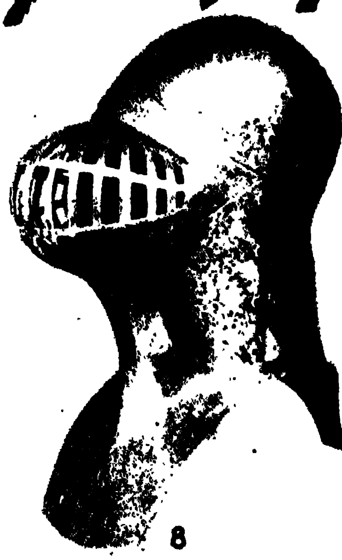
No. 1. An Italian of the sixteenth century wore this charming costume over his suit of armor. No. 2. An Austrian weapon of the seventeenth century. No. 4. A sixteenth century German halberd. No. 6. Knight and horse in full armor. No. 7. German armor of the seventeenth century. No. 8. This Viennese helmet of the fifteenth century could not have been very becoming to the wearer, but it gave good protection.


6

Some of the world's most fantastic armor comes from Japan. Nos. 3 and 5 show two Japanese suits of eighteenth century armor. They are made of a number of metal plates held together with cords of silk, which were of different colors—red, purple, green—according to the wearer's rank. Notice the plumed helmet below the upraised hand in Fig. 3. No. 9 is German armor of the fifteenth century.


7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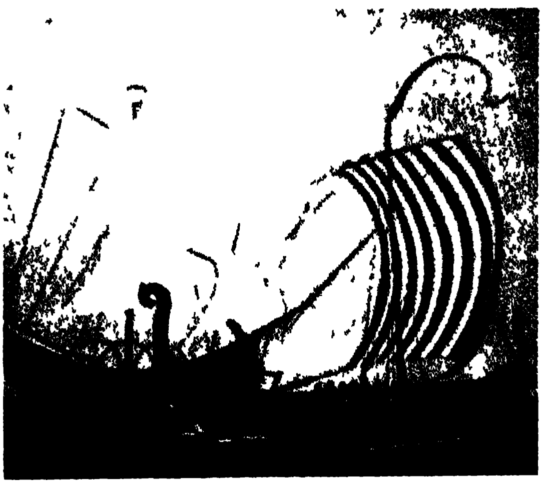
9

Photos by Metropolitan Museum of Art

Yet the tall galleons of the Armada (ar-ma'dȧ), that proud Spanish fleet, and the swift English vessels of Queen Elizabeth that defeated them, wore no armor against one another's shots. Even in Napoleon's time, around 1800, the thick oak sides of a boat were its only protection. But along in the middle of the past century, when the guns were getting far more powerful, the old wooden ships could not stand up against them at all. So since then warships have gone armored like the knights of old. One of the earliest and most famous battles of armored vessels was the fight between the "Monitor" and the "Merrimac" in our own Civil War. Their armor plate was made of wrought iron. Later a plate was made with steel on top and iron underneath, and after that came nickel-steel plate, part nickel and part steel, which is stronger still.



In the early days of sea warfare no one dreamed that vessels would be able to carry on a fight over miles of separating water. When the viking ship you see above attacked a merchant vessel, the fighting was hand to hand. It was centuries later, in our Civil War, that one of the first battles between armored vessels took place. You may see it at the right, it is the famous encounter between the "Monitor" and the "Merrimac."

Photos by [illegible] Service and [illegible] & Co.

Why a Shell Must Spin

The new guns that began to be made half a century or so ago were of the same general kind as those still in use. They are grooved inside to make the shell spin as it flies out, that keeps it going straight. They fire long, pointed shells, which are much more swift and go much farther. About the same time machine guns were invented, small guns that keep on firing automatically while a string of cartridges is fed into them. Smokeless powder came into use, while dynamite and other deadly explosives took the place of the old gunpowder. Guns began to be made all of steel.

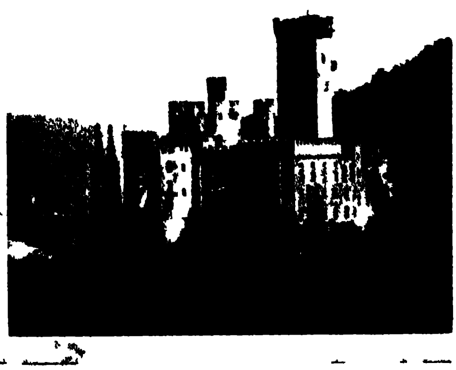
We moderns do most things on a larger scale than the older peoples ever dreamed of, and unfortunately killing one another is by no means an exception. By 1914 the nations were facing each other armed to the teeth, with huge navies and armies all ready to spring forward at the word of command. In that year World War I broke out, and for four years Europe was one vast battle-field, with soldiers pouring into it from the ends of the earth—from Asia and Africa and America and the islands of the sea. The wide lands laid waste, the treasure spent, and the millions of men killed or wounded in this way make the wars of other times seem merciful by contrast. And of course

Photo by Metropolitan Museum of Art

The inhabitants of this German town of the Middle Ages must have felt fairly safe behind their fortifications. At the first hint of danger they could pull up the drawbridge you see across the moat. And if the enemy was able to drain or fill in the moat, the townsmen were still protected by their massive walls.

the First World War saw many new or altered ways of fighting, whether in attack or in defense

It was a war in which masses of men, heavily armed and advancing in close formation, were hurled against other masses, or against the fortified positions that had been set up to hold them back. Gun fire mowed down the oncoming troops as a reaper mows down grain. Such loss of life in battle was never seen before or since. Early in the war the opposing armies dug in—that is, neither side was able to win a clear-cut victory in the full clash of battle, and so, in order to hold their lines firm, they dug a network of deep, narrow trenches in which soldiers could be out of the way of bullets and yet hold their ground and be ready to spring at the enemy in case of attack



No traveler can boast that he has seen the world until he has taken a trip up the Rhine. Perched high on the hills which flank the river are castles of the Middle Ages. Their gleaming turrets and frowning battlements are one of the most romantic sights in the world. Above is one of the finest of them; it saw brave fighting in the olden days.

For eating and sleeping the men of World War I went back to dugouts scooped out of the earth a little to the rear of the front-line trenches. Through summer heat and winter cold, in snow and rain and mud, the soldiers lived in the trenches for four long years. From time to time one side or the other would launch an attack, in the hope of breaking through the enemy's lines, rolling his armies back, and finally getting to Paris or Berlin—or to a hill or wood a mile and a half away!

But as a rule their gains were hardly worth counting, especially in the face of the terrific losses. Great masses of barbed wire were wound back and forth in front of the trenches to hold the enemy at bay while

his men could be raked with bullets. And the open space between the trenches—a place of horror and desolation which the soldiers called "no man's land"—was full of craters and shell holes and had been planted with mines that exploded when they were trod upon.

Most terrifying of all, for days before an attack the big guns pounded trenches and fortifications with heavy shells to destroy men and emplacements. It was the only way for the attacking force to have any chance of getting beyond the enemy's front-line trenches. When the "zero hour" came—the moment at which the men "went over the top"; that is, leaped from their trenches and ran toward the enemy's lines—friendly guns laid down a "barrage" (bå'razh'), or wall of shell fire, ahead of them, like a fiery curtain to clear the way. Often this was supplemented by great streams of flame, sent forth from machines called flame throwers that spurted burning oil into the faces of the enemy.

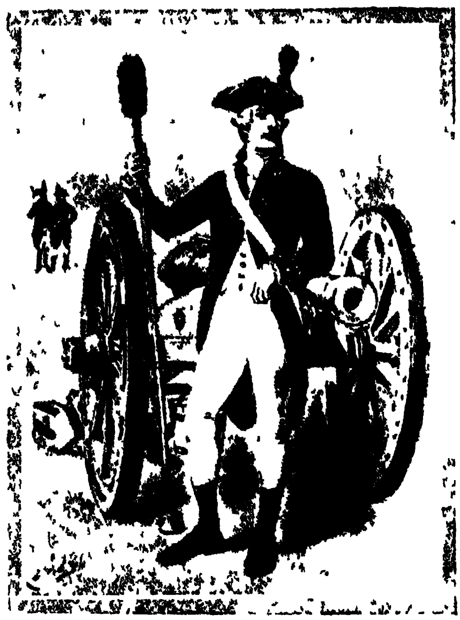


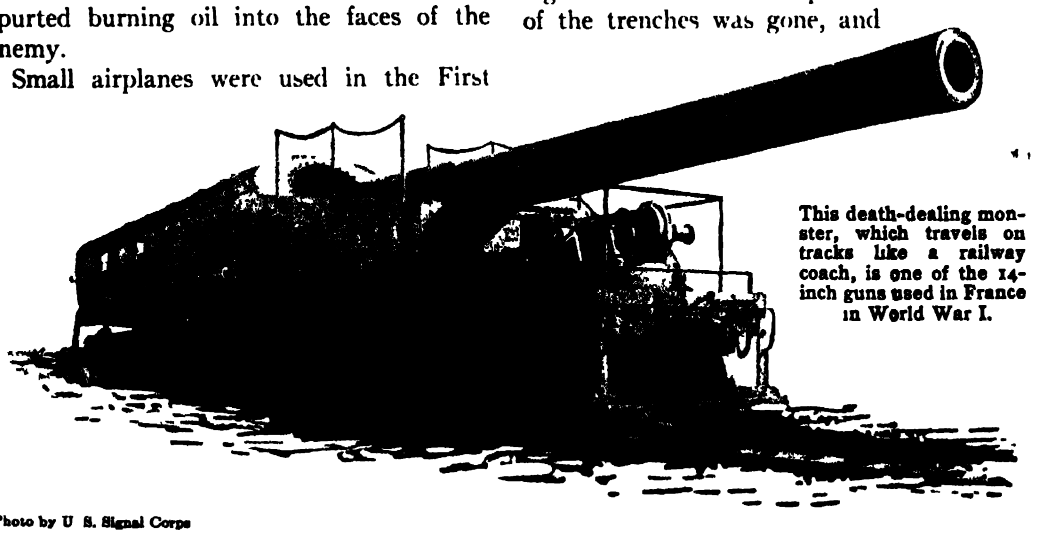
Photo by U S Signal Corps

Here are a cannon and a cannoneer of the American Revolution. Compare this picture with the one below and you will see what has happened to the cannon in a little over a century and a half.

Small airplanes were used in the First World War but almost entirely for reconnaissance (rê-kŏn'ǎ-sǎns)—or getting information behind the enemy's lines. Giant airships, or dirigibles (dĭr'ĭ-jĭ-b'l) great cigar-shaped balloons that are propelled by a motor did the same kind of work and also a little bombing, but they were easy to puncture with bullets and shells, and when that happened the gas leaked out and the airship collapsed or else it took fire and went up in flames On sea patrol they were much more useful, and in 1942 43 were used for that purpose along the coasts They were excellent at spotting submarines.

The submarine was one of the outstanding weapons in both World Wars, and was most successful It was Germany's answer to the naval blockade which the British threw around her in order to starve out her people.

The Second World War saw a brand new type of warfare, made possible by the perfecting of the tank and the airplane. The old war of the trenches was gone, and



This death-dealing monster, which travels on tracks like a railway coach, is one of the 14-inch guns used in France in World War I.

Photo by U S. Signal Corps

once more a vigorous attack in open fighting could win the day. It was a war of "movement." At the very start Germany struck so swiftly and successfully that her method of offense has set the pattern for all present-day warfare. It is called the "blitzkrieg" (blĭts'krēg) - or "lightning war" for reasons that are only too plain.

In the main the blitzkrieg depended upon hitting hard and fast, and to do this it made large use of planes and tanks and motor vehicles to attack military points and to move troops and supplies. Its whole theory was to throw the enemy into confusion and then strike him hard before he could get himself together. Planes did most of the work at the outset no fortification was able to keep them out. They flew over the territory of the enemy in great waves- hundreds upon hundreds of them. First of all, they bombed airports, hoping to destroy the opposing air force while it was still on the ground, or at least to plow up the landing fields so that defending planes had no bases to work from.

The Work of the Parachute Troops

Following this, infantry was landed by parachute to occupy the airfields whenever possible. They got machine guns, food, and other supplies even tanks by parachute, and put their airfields in shape for the immediate landing of large bodies of troops by transport planes. These air-borne troops reinforced the early arrivals and helped in attacking other strategic points—as any ordinary infantry would do.

Meanwhile, the attack from the air was still going forward. Sharp battles were fought in the skies between the invading air force and the defending fighter planes. Of course, if the invading planes were worsted, the blitzkrieg was stopped then and there. But if the enemy could win what we know as "control of the air" and had plenty of planes to maintain it, the country was doomed.

The invaders dropped enormous explosive bombs on highways, bridges, railroad centers, docks, oil tanks, warehouses, stores of ammunition, and other military supplies. They shattered power houses, waterworks, dams and reservoirs, sewage systems, and any other public works necessary to the life

Photo by U. S. Army Signal Corps

With his fall broken by a 'chute this paratrooper will hit the ground about as hard as if he had jumped 13 feet. His high shoes will not jerk off when his 'chute snaps open, and they will support his ankles when he lands. Notice the cup he wears to guard his chin.

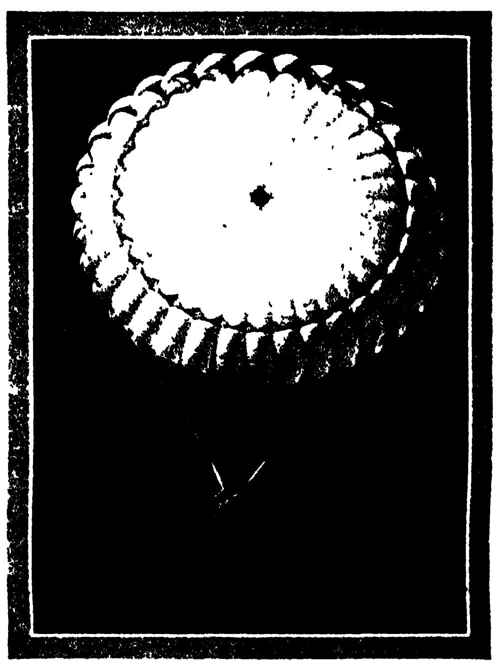


Photo by U. S. Army Signal Corps

A parachutist must fall a considerable distance before he pulls the "rip cord" that will open his parachute. After that his descent is easy. Its direction he may control by manipulating the ropes of his parachute.

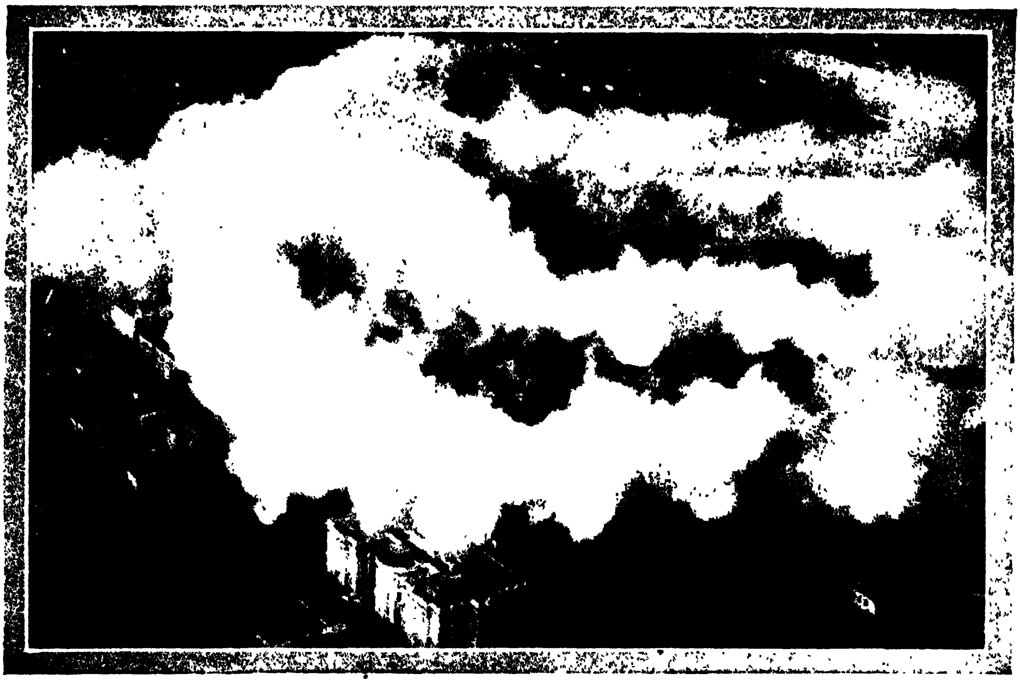


Photo courtesy U S Air Force

Here you see a smoke screen which an airplane has laid to hide a city from its enemies in the air. Smoke is poor protection, however. The bombardier can locate his targets by radar, which is not affected by smoke.

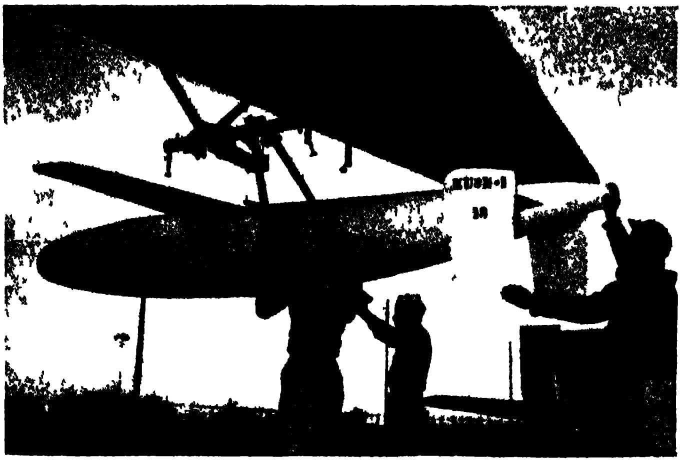
of the country. Dive bombers shelled anti-aircraft guns. Small groups of engineers destroyed bridgeheads, passes through woods, and any similar points of military value. Light and medium bombers attacked gun positions with smoke shells to spoil the gunners' aim, and heavy bombers shelled towns and dams and strongly built points of every sort. The planes that were thundering overhead dropped thousands of incendiary bombs to start raging fires that hindered the movement of troops.

Spies and secret agents and, when possible, a "fifth column"—inhabitants friendly to the enemy—carried out assigned tasks of horror and sabotage (să'bô-täzh')—or wilful destruction. They spread wild and alarming rumors, and lies to destroy morale, and committed murder if it served their ends. Every effort was made to sow terror and confusion among the people and to start them fleeing in panic along the roads, which became so crowded with refugees that soldiers could not be sent quickly where they were needed. Wherever troops were seen, dive bombers centered a withering fire upon them. In France and Poland the German invaders were completely ruthless in shooting at fleeing civilians.

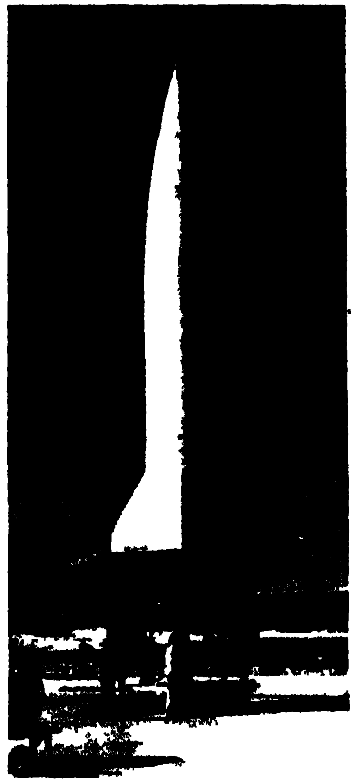
When a country and its people were utterly disorganized; when ambulances went dashing along streets and roads and people were trying to care for the wounded; when oil tanks, warehouses, and railroad depots were in flames and fire engines were at work in a frantic effort to keep the fires from wiping out whole cities, swiftly through the drifting smoke came the tanks. Somewhere in the fortifications along the country's border they had found some point weaker than the rest. There they had centered their vicious attack, with artillery, planes, and perhaps infantry to help them. Once a break was made, they poured through it like water through a broken dam.

The Invasion March

The blitzkrieg attackers brought with them fast armored cars and large numbers of armored motorcycles. An "umbrella" of planes escorted them overhead for protection



Official U S Navy Photograph



PUSH-BUTTON WARFARE is still in the minds of the inventors, but they have given us some of its weapons The most important of these are rockets and guided missiles and pilotless aircraft Two of the most famous rockets are shown at the right The upper one is the V-2, which the Germans sent against London at the close of World War II It is 46 feet long and reaches a speed of 2,800 miles an hour Its fuel is ethyl alcohol and liquid oxygen A gyroscopic system keeps it steady In an ascent made in 1949 at the Army proving ground at White Sands, New Mexico, it carried with it the smaller rocket shown below it This is known as the WAC Corporal It is 16 feet long and can exceed the speed of sound Its fuel is red fuming nitric acid and aniline The WAC Corporal, let loose from the V-2 when that rocket had reached its limit, went on up to a height of 250 miles a record It sent back valuable information about the upper air Scientists expect some day to be able to send missiles 10,000 miles

Neither of the rockets at the right is a guided missile, though the V-2 has been controlled in experimental flight The one at the top left is a guided missile, carried on the wing of a plane It will be launched from the plane and controlled from another plane Such missiles seek out their targets on land, sea, or in the air by means of radar, radio, television, or devices sensitive to sound, heat, and magnetism. In World War II the "proximity fuse" was a device of this general kind It was an extremely tiny radio sending and receiving set that helped a shell hit its target

Missiles may be launched from land, sea, or air, and seek targets in the air, on the ground, or on the sea Pilotless aircraft may be launched and controlled in the same way Both missiles and planes may be swerved in their flight, and eventually will perhaps be able to carry a device that will enable them to recognize their target when they see it and make straight toward it

Missiles are classified to show the place where they are launched and their destination GTG is ground to ground ATG is air to ground ATS is air to ship And STS is ship to shore

One of the swiftest guided missiles is the "flying stovepipe," which has a ram-jet engine Such engines have more power than any other kind, but they are not efficient until they reach about twice the speed of sound and they take a great deal of fuel A small rocket engine can be used to "boost" them up to the necessary speed The flying stovepipe is a cylinder with valves and a fuel compartment Air comes in at the nose, and because of the missile's speed is highly compressed. Valves regulate the mixture of air and fuel and control the exhaust. They are about the only moving parts The missile moves forward on much the same principle as a squid in water

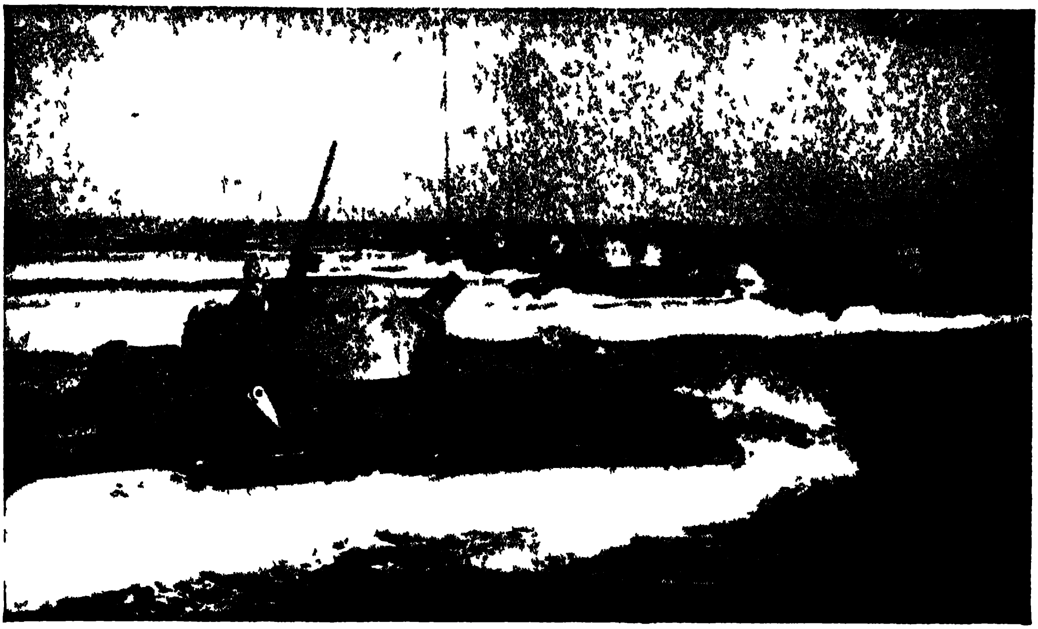
Already the Army is planning rocket space ships that shall circle around the earth like small moons above our atmosphere We do not know exactly what their use will be, except that from them we can direct 4,000-mile-an-hour missiles sent against rockets of the V-2 type.

Photos Upper right courtesy General Electric Company lower right U S Army Signal Corps

Official U.S. Navy Photograph

The airplane carrier is one of the wonders of modern warfare. Here is a modern giantess of the United States Navy, with some of the mechanical birds that come to roost on her decks.

against artillery. The dive bombers' chief business was to knock out any guns that might go into action. In columns sometimes as much as a hundred miles long the "mechanized" forces penetrated into the heart of the country, withering all resistance under a wicked fire from machine guns and cannon, seizing or destroying vital points, holding important positions. Because tanks are not equipped to defend themselves and therefore



Official U. S. Marine Corps Photo

When these amphibious tractors reached the shore of Okinawa, they did not stop, but rode inland against the enemy on clanking caterpillar treads. The "Amphtrac" is but one of the strange children of sea-borne invasion. It was built to clamber over the reefs and sandbars which surround many islands in the Pacific.

must have protection: bodies of infantry in armored vehicles seized all anti-tank guns and armored trucks kept the tanks supplied with ammunition and other supplies.

The Infantry's Job

Close on the heels of the tanks came the infantry, the men who fight on foot. It was their business to take possession of the country. But they did not come marching. Instead they rode in swiftly moving trucks bringing their equipment with them: machine guns which could be set up in three minutes, anti-tank and anti-aircraft guns, automatic rifles, automatic pistols, tear-gas bombs, small cannon, and other equipment. With them were large numbers of men mounted on motorcycles to protect the flanks of the column from any defenders along the route of march.

The infantry soldiers, thoroughly trained for their job, fanned out rapidly to seize radio stations, telephones, telegraphs, police stations, railways, and supply centers. Usually they easily "mopped up" any armed resistance, though there were always some battles with such forces as the invaded people could get together. Generally, the nation's plan of defense was so completely disorganized by the assault from the air that the battle was almost won before the troops met. One after another Poland, France, and the nations to the south of Germany were in the enemy's hands before anyone knew what was happening. While radios blared orders to the civilians and confused them with false news, Storm Troops took over all means of communication and transportation. Engineers came hard on their heels to repair the communications and make ready for the occupation forces, which were to live as masters over a new slave state.

Attack by Sea, Too

Invasions in which battleships and submarines took part naturally moved a bit more slowly, but attack by sea was part of blitz warfare, too. In the case of Norway a whole fleet of German ships suddenly arrived just off her inner fortification of Oscarsborg and almost immediately planes, swooping from nowhere, were raining bombs over the capital city. Simultaneous attacks were made against some seven or eight ports. At one, what appeared at first

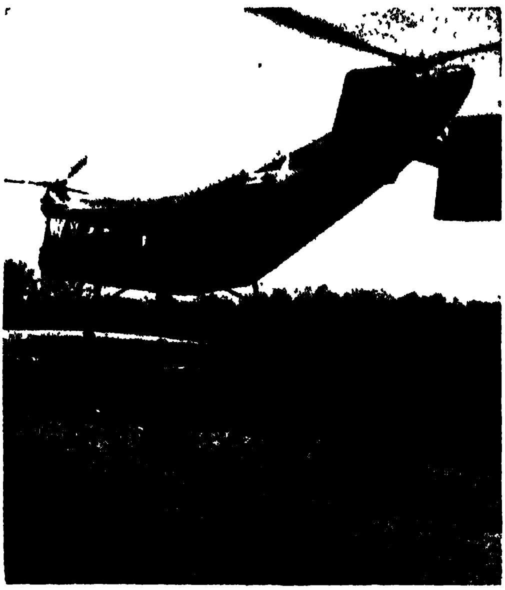


Photo courtesy U S Marine Corps

These U. S. marines are practicing combat operations in enemy territory. Helicopters loaded with combat teams transfer both men and equipment from nearby aircraft carriers. Now that this airplane has landed a 75-mm. pack howitzer it can take casualties back to their carrier base.

to be an innocent fleet of iron ore boats turned out to be armed troop ships from whose holds poured hundreds of well-equipped infantrymen. From then on, the occupation proceeded in about the same way as has been described.

Modern Warfare Requires Exact Timing

Modern warfare, no matter by whom it is carried on, calls for careful planning and almost perfect timing in order that all operations may go smoothly and all advantages may be taken before the surprised defense forces can organize. It takes great preparation, for everything must be planned to the last detail and then carefully rehearsed. Both men and machines have to be tested, because even the best machines have to be operated by experienced men.

Of course no one can predict exactly how invasions of the future will be carried on or what new armaments will be used. New strategies and new weapons with which to carry them out are constantly being developed. Today, more than ever, technical knowledge and clear thinking are as necessary as are courage and the willingness to fight.

Learning the Plan of Battle

A modern fighter, to the youngest private, knows what he is about. Before he goes into action his officers have explained to him carefully the whole plan of the engagement. He knows the lie of the ground almost as well as he knows his own back yard. Every officer down to the sergeant has an excellent map of the land his troops will fight over called the terrain (tĕ-rān′) and every man under him is made to memorize it.

Those military maps are marvels of skill. They are made from photographs taken from airplanes by remarkable nine-lens cameras that are not inconvenienced by clouds or darkness, but can take photographs under almost any lighting conditions. At one loading they can make a photographic map of a region two hundred miles long and several miles wide, and can outwit the most elaborate camouflage.

In World War I it was the artillery that was the backbone of the army, and it still is very important. There is a 16-inch howitzer (hou′ĭt-zẽr), a cannon which like the "mortar" sends its projectile in a high arch, or curved "trajectory" (trȧ-jĕk′tŏ-rĭ), whereas a "gun" sends its projectile almost in a straight line. The length of a cannon is measured in terms of its caliber, which is the diameter of the projectile and also of the long chamber inside the barrel. Mortars are not over twelve calibers in length which is to say, twelve times the caliber. Howitzers range from 13 to 30 calibers, and guns are over 30 calibers. The howitzer is useful for shelling a point on the other side of a high hill. An officer in an observation plane or at some other point from which he can see both the gun and the object to be shelled, will make a number of mathematical calculations which make it possible for him to give directions for taking perfect aim.

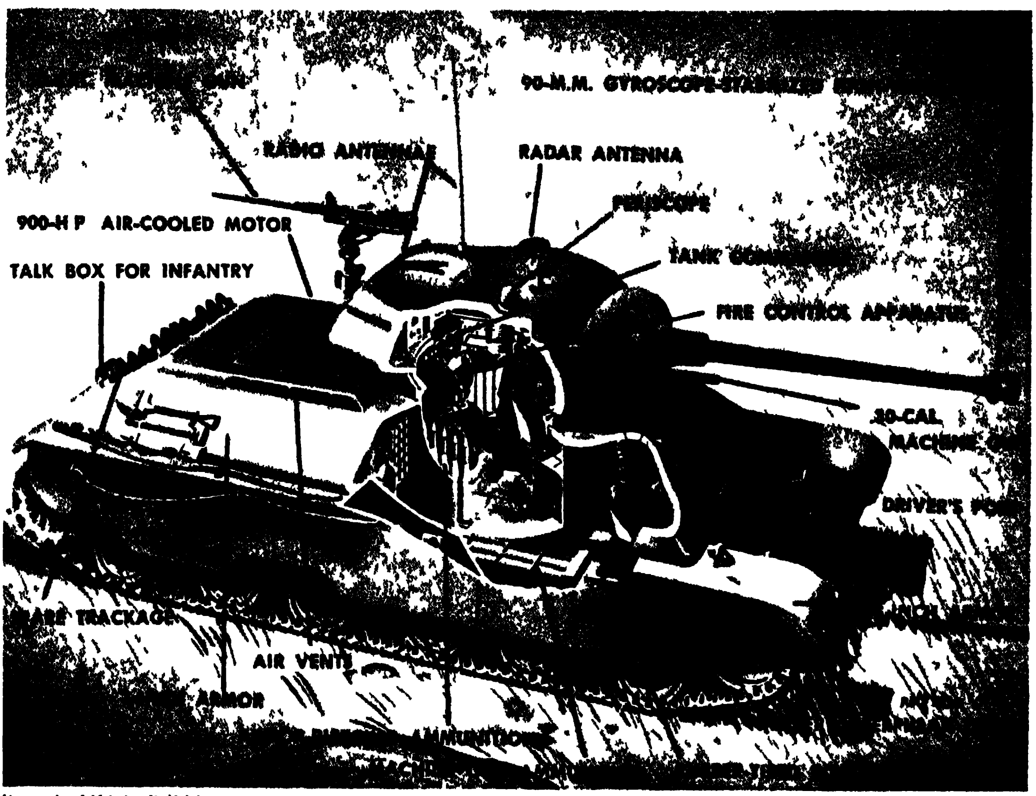
Electricity Works the Big Guns

The largest cannon are loaded by electricity, and are set in concrete emplacements. In fact they are often set in pits, from which they rise, fire, and then sink back out of sight again, like great dragons that spit forth

their venom and then retreat to their lairs. Like all guns in permanent emplacements, they may even be aimed and fired by means of an electrical connection which makes it possible for the gun crew to be in a safe spot some distance away. The field artillery does not use cannon heavier than its 240-mm howitzer that is, one with a caliber of 240 millimeters, an inch being just a shade over 25 millimeters. Field artillery must move over the battlefield, and the pieces have to be mounted on vehicles. The cannon most used in the field is the 105-mm howitzer.

All cannon nowadays send shells instead of solid bullets such as rifles and machine guns use. A shell is a cigar shaped case of thin steel, and always contains a high explosive usually with a base of TNT together with a second explosive, or detonator (dĕt'ō nā tẽr) often tetryl (tĕt'rĭl) or lead azide (az'īd) which sets off the main charge. No shell can go off until a delicately adjusted fuse sets off the detonator. The VT, or "variable time," fuse holds a tiny radio sending and receiving set that lets it go off only when near the target.

Shells are of various kinds. A high-explosive shell, the commonest kind, explodes when it strikes and destroys whatever is in the way. Often the fuse is set so that the shell will penetrate an object a short distance before exploding, and in that way do still greater harm. Sometimes shells are filled with shrapnel, or small bullets that scatter as the shell bursts. Sometimes they are full of poison gas mostly phosgene (fŏs'jēn) gas and mustard gas the first, and most deadly, intended to suffocate and blind a man, and the second, which is really an oily liquid, intended to attack the lungs and nasal passages and to inflict terrible burns on the skin. Every shell is made with extreme care, almost



Drawn for LIFE by R H Klep

This drawing represents the ideal tank. It has never been built and probably never will be. In actual use some desirable features cancel out others, so the present tanks are a compromise and therefore far from ideal.

Photo by U S. Army Signal Corps

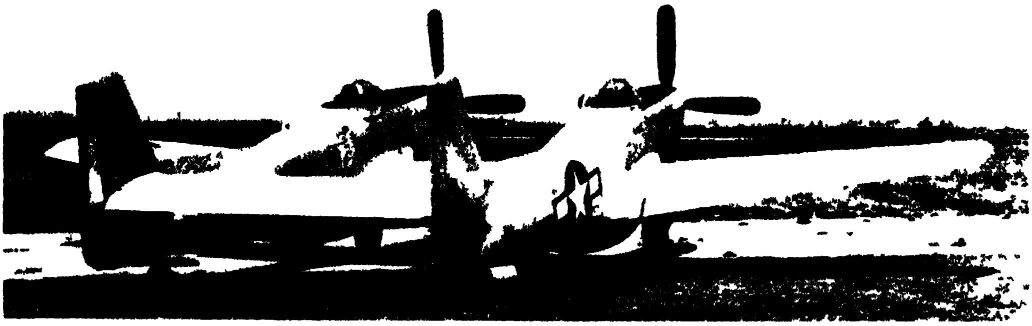
Beside the wreckage of a German warplane these soldiers in World War II have brought their 155-millimeter gun into position on a captured airfield in Germany. Fast-moving artillery like this is a vital factor in warfare.

as if it were a fine watch. The great munition factories behind the lines are as important as whole armies of soldiers.

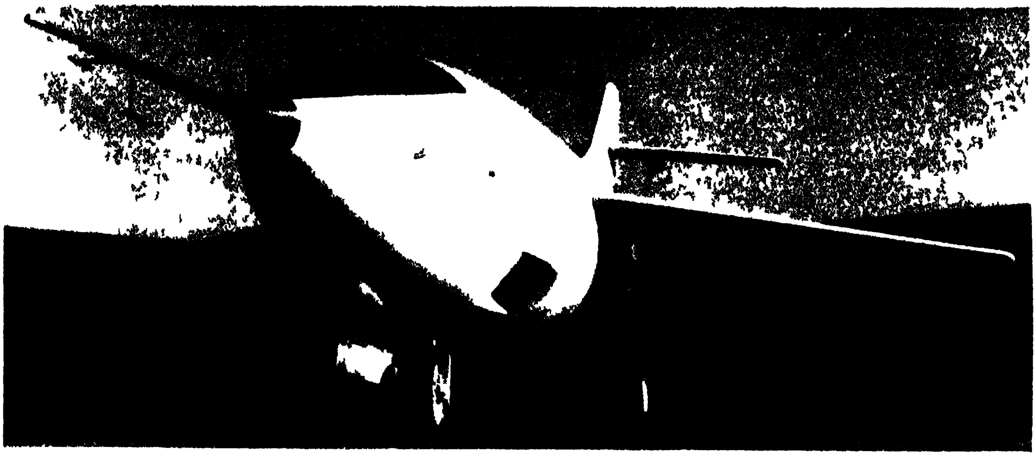
Bombs are about like shells, but they are dropped from planes, are thrown by hand, are jet- or rocket-propelled, or set in the place where they are intended to go off. They are of many kinds. For air raids there are: 1) the deadly atomic bombs, only one of which will destroy a large city; 2) high-explosive "demolition" bombs, which may weigh as much as 22½ tons and can reduce houses or even whole towns to dust and rubble; 3) the smaller "fragmentation" bombs, which are shattered into a thousand fragments that bring death and destruction; 4) "incendiary" (ĭn-sĕn′dĭ-ā-rĭ) - or "fire-starting"—bombs, which can burn with a heat of 6,300° F., half as great as the heat on the surface of the sun. Time bombs have a time fuse that sets them off hours or perhaps days after they land.

Then there are bombs called "mines," which are set at sea to go off when a ship touches them or, in the case of magnetic mines, to go off when a ship's iron bulk comes near. Others are set off by sound from a ship's engines or by pressing a button on shore. Ships can outwit bombs by dragging paravanes (păr′ā-vān) from the prow great cables fitted with steel jaws to cut the mines from their moorings. Against magnetic mines ships wear a "degaussing apparatus," a girdle of electric cables that carry an electric current to neutralize the mine's apparatus. Then there is the "depth bomb," arranged to go off under water and crush the thin walls of a nearby submarine with the shock of the explosion. And there is the very deadly torpedo, which is a good deal like a tiny submarine, since it has a propeller, a rudder, and can travel to its target under its own power, driven by a compressed-air engine or by electricity. A torpedo can sink a large ship.

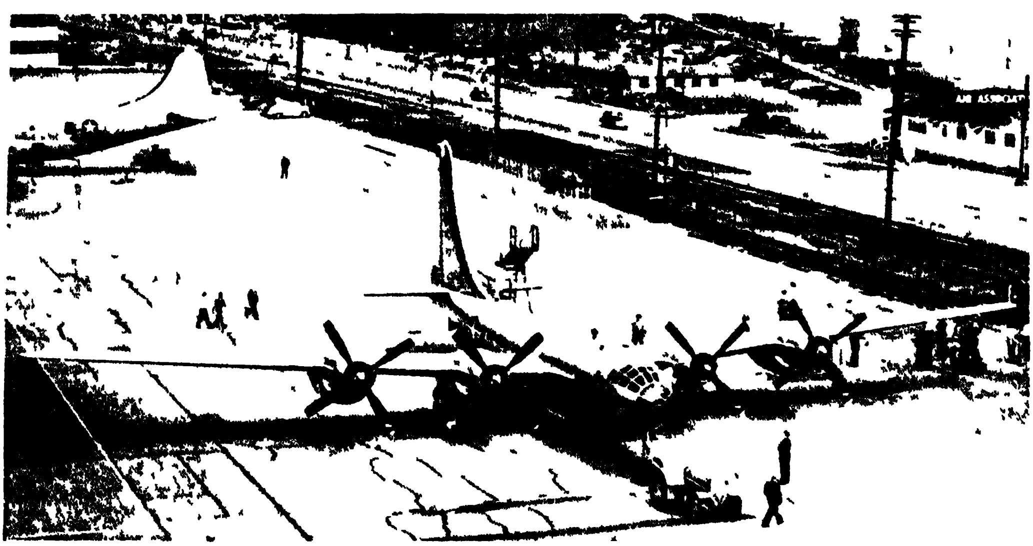
But the most deadly of soldier's weapons is the machine gun, the basic weapon of modern warfare. It is the lineal descendant



The Twin Mustang (P-82), a long-distance escort fighter, allows the two pilots to relieve each other



The Navy Skyrocket (P-84) has swept-back wings and can drop off the whole front end including the pilot's compartment for quick escape Air scoops at the sides feed the turbojet engine A rocket engine adds power



Photos courtesy U S Air Force and U S Navy

This is the plane the B-50 bomber —that made the first non-stop flight around the world (1949). It was fueled four times in mid-air by B-29's of World War II fame. It is a B-29 with higher tail and more power.

Photo by Douglas Aircraft Corporation

Without a hand at the controls, either in take off, landing or flight, this plane —the Douglas Skymaster (C-54) —has flown across the Atlantic guided only by a "mechanical brain." Two ships at sea controlled it by means of radio signals. In World War II the Skymaster saw service transporting cargo and troops. Since then it has been the mainstay of the Air Force in operating the famous Airlift by which hundreds of thousands of tons of food and supplies have been carried over the blockade that Russia set up around Berlin.

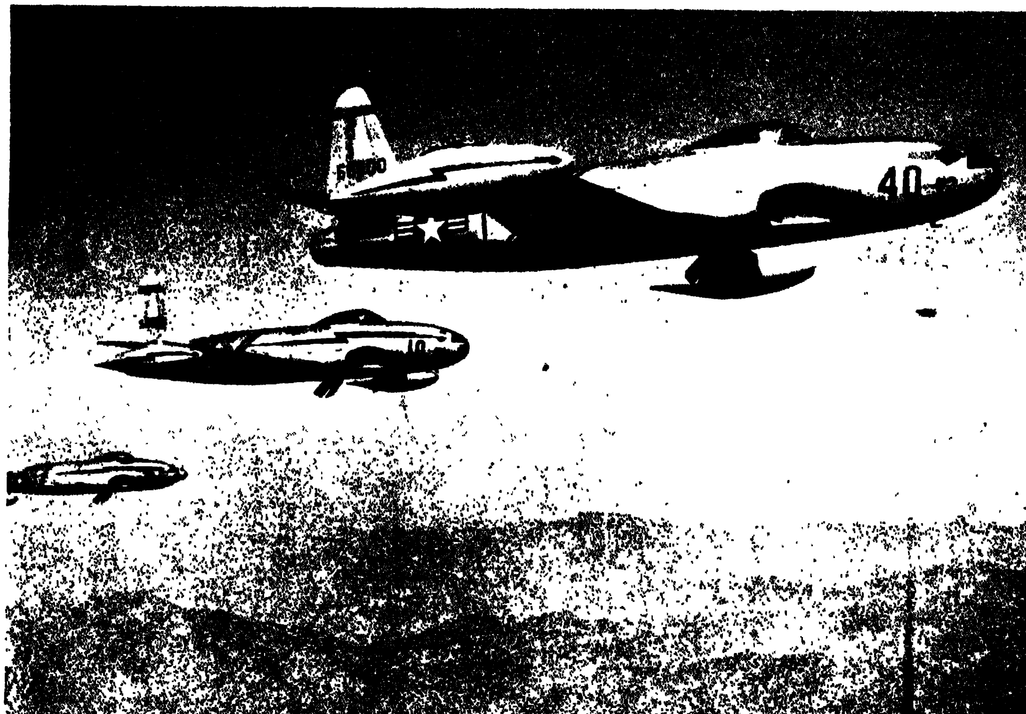


Photo by U. S. Air Force, Washington, D. C.

The Shooting Star (F-80) was the first jet plane the American Army put into service. It saw fighting in World War II, when it was the world's fastest plane. On each wing tip is a container for extra fuel to be dropped when the fuel is used up. The two air ducts are just in front of the wings.

of the old-fashioned muskets and flintlocks that our ancestors used, and of the fine Springfield rifle that our soldiers carried in the First World War—probably the most accurate gun that was ever made. But after the American inventor John M. Browning (1855-1926) had perfected the machine gun, its speed made it almost a new weapon.

Machine guns are of various sizes, ranging from the little five-pound semi-automatic carbine (kär′bīn)—which on repeated pressure of the trigger will deliver fifteen .30-caliber bullets in quick succession—all the way up to a 40-mm. cannon, our largest automatic weapon—called a cannon because it has to be permanently mounted. All of the machine guns fire automatically—that is, one pull of the trigger will let out a continuous stream of bullets, like a stream of water, as many as 700 a minute or, for continuous firing, 150 a minute or thereabout. The cartridges are fed from a belt running through the gun behind the barrel, or from a magazine a boxlike container attached to the gun. On some of the small automatic weapons the gases escaping from the explosion furnish the power for the mechanism that ejects the used cartridge and the cartridge clip when it empties. In all the larger guns it is the force of the recoil that does this. Of course the guns used in planes are all automatic.


Photo courtesy U. S. Air Force

The speed and altitude of fighter aircraft hinder the proper circulation of the blood. So to keep him from blacking out and losing control of his plane, the pilot wears a "G" suit which supplies pressure wherever the blood begins to stop in the veins.

The fine Garand rifle, issued to our soldiers, is semi-automatic—that is, the trigger must be pulled for each shot. It can fire fifty shots a minute, and is one of the best of all rifles. One man with a Garand can replace in firing power three to six men armed with Springfields.

The Amazing AA Guns

Perhaps the most amazing weapons are the anti-aircraft guns—"AA" guns or "ack-acks." They must take aim in the dark at an invisible airplane flying 30,000 feet high at 200 miles an hour—and must allow for the fact that an AA shell will take 20 seconds to climb up there. As a matter of fact, the gunners do not really expect to hit their plane. If their shell explodes fifty yards from it, one of the fragments will be fairly likely to damage it.

To help them they have a marvelous instrument called a director—a box containing two telescopes with which to follow the course of the plane and miraculous devices that use the telescopes' information to figure out the position, speed, and direction of the plane. And then still other devices will tell the altitude, temperature, atmospheric conditions, and speed and direction of the wind, all of them things which must be considered. At night a "triple-eared" sound locator revolves in the direction of the sound and helps the 60-inch searchlight to hunt out the plane among the stars. AA guns range from the 37-mm. machine gun up to a 4.7-inch cannon. The 105-mm. gun can send a 33-pound shell straight up for 27,300 feet. Larger guns reach as high as 7½ miles. Against low planes ordinary machine guns are best.

War planes are of a number of types, each designed to do a particular job. They fall into three main classes: heavy bombers, which are of long range and slower than the rest, and carry a heavy load of bombs to be dropped from high levels on enemy territory; attack planes, or dive bombers, which bomb from low levels and attack troops, ships, forti-

Photo by U S Army Air Corps

As you may see above, a glider is a thing of grace and beauty, carefully designed to use every breath of air to best advantage. It has no engine, but relies entirely on the wind to keep it up. The wings and controls resemble those on an airplane, but in a glider the pilot is seated farther forward and the weight is distributed in a way to make up for the lack of the motor's weight.

The idea of the glider is not new. Men have been experimenting with glider models for 150 years, and in that way worked out certain fundamental principles of the airplane. The older gliders were designed to take off from a low elevation and "slide down a current of air" to the ground. Only lately have we had the "soaring glider," or "sailplane," which in the hands of a skillful pilot can be made to mount to high altitudes and go long distances on a succession of rising currents of air. One of these fragile little contrivances has traveled over 400 miles and reached an altitude of 16,000 feet, staying in the air more than 36 hours.

Until quite lately gliders were regarded mainly as toys, but now all that is changed, for it has been found that they can be towed through the air by a high-powered plane and can even be hitched one behind another to make a glider train. The fact opens up endless possibilities. Gliders are inexpensive to build, and if put into wide use would reduce the cost of air travel enormously. Perhaps some day we shall have trains of them going in all directions through the sky. Already they have been of great service in war. When used to invade enemy territory they can be left where they land without any great loss, once they are emptied of passengers or cargo.

fied positions, or other small targets; and fighter, or pursuit, planes, which must protect their own cities or troops or ships or heavy bombers against attacks. Long-range bombers are usually too slow and unwieldy to be able to fight very well. The big Consolidated Liberators (B24) and Boeing Flying Fortresses (B17) were the first long-range bombers to be so heavily armored that they did not need protection from fighter planes.

Then, too, there must be planes to work at different altitudes, and sturdy craft to go in and do the rough work in preparation for other swift and highly accurate machines to come in for the "kill." The United States Air Force has war planes of many types—tankers for refueling in mid-air, trainers, transports for troops and supplies, and gliders to be hitched together and towed through the air. The first letter of a plane's identification symbol tells its use. For example, a "B" is a bomber, a "C" a cargo carrier, and an "F" a fighter. Those which direct unpiloted planes and guided missiles by remote control are designated by a "D." Some pilotless craft are controlled from the ground.

Tanks, though used a little in World War I, came into their own when the Germans sent their famous Panzer (pan'tsĕr) Divisions into France in 1940. The weapon had been invented in order that machine-gun fire might be safely taken into enemy-held territory. Those heavily armored giants can turn all ordinary bullets, and on their caterpillar treads can go anywhere on an ordinary battle field, though they need protection from infantry or planes. They are of various sizes, but our largest, the General Sherman (M4) weighs more than sixty tons. All carry several machine guns. The armored, or mechanized, force has more than two hundred types of tanks and wheeled vehicles, many of them armored and provided with machine guns. Each had a special work to do.

For infantry use against tanks our Army had a strange-looking rocket gun nicknamed the bazooka. At the war's end millions of rockets were being used by all our fighting forces and for every sort of purpose. Elsewhere we have described their action. The German V-2 rocket, winged—like a plane—has gone up 114 miles in tests made in New Mexico and has reached a speed of 3,500 miles an hour—too fast to be seen or heard. Certain new missiles carry "homing" devices to guide them to their target.

Reading Unit No. 4

HOW BIG IS IT? HOW HEAVY IS IT?

Note: For basic information not found on this page, consult the general Index, Vol. 15.

For statistical and current facts, consult the Richards Year Book Index.

Interesting Facts Explained

The first crude pair of scales, 10-371
What the weight of a thing really is, 10-371
How the ancient Egyptians weighed things, 10-371, 373
The Latin meaning of our word "mile," 10-373
Why we write "lb." for "pound," 10-374
When a pound was not a pound, 10-374
The different measures of distance and weight that we use, 10-370, 376
The length of the meter, 10-376-77

Things to Think About

What kind of weights and measures were used when Queen Elizabeth ruled over England?
Why do we use the system of mills, cents, dimes, and dollars?
Why do we not use the "metric system" in America?
What are the great advantages of the metric system?

Related Material

What is the difference between mass and weight? 1-303
How can we weigh the earth without scales? 1-10
How can we find out how much a ship weighs? 1-468-74
How is it that a heavy steel ship will float? 1-471
How does centrifugal force influence the force of gravity? 1-122, 136
At what speed do objects of different weights fall? 13-397-98
What is meant by the "density" of any substance? 1-467-74

Practical Applications

What system of weights should we use if we wish to get the exact weight of anything? 10-377
What value is the metric system to scientists? 10-377

Leisure-time Activities

PROJECT NO. 1: Make a balance, 10-374
PROJECT NO. 2: Make a steelyard, 10-374

Summary Statement

There are many different ways of weighing and measuring things, but the metric system is the only scientific way of measuring and weighing that the world has ever had.

Photo by W. & T. Avery, Ltd.

A king in Northern Africa about 550 B.C. is watching sailors weigh their cargo of asafetida, a common drug that our grandparents used to wear in little sacks about their necks to keep the smallpox away.

Photo by W. & T. Avery, Ltd.

This Roman butcher, who lived in about 150 A.D., had his shop in the open air and weighed his meat on steelyards. They are here shown in use, suspended at the end of the rack on which the meat is hung.

WEIGHTS AND MEASURES

Foreign

Denominations	Where Used	American Equivalents
Almude	Portugal	4.422 gals
Ardeb	Egypt	5.6188 bu
Are	Metric	0.02471 acre
Arratel or libra	Portugal	1.0119 lbs
Arroba	Argentine Republic	25.32 lbs
"	Brazil	32.38 lbs
"	Cuba	25.36 lbs
"	Paraguay	25.32 lbs
"	Venezuela	25.40 lbs
" (liquid)	Cuba, Spain and Venezuela	4.263 gals
Arshine	Russia	28 in
(sq.)		[illegible]44 sq. ft
Artel	Morocco	1.12 lbs
Baril	Argentine Republic	20.077 gals
	and Mexico	20.0787 gals
Barrel	Malta (custom)	11.2 gals
Berkovets	Russia	361.128 lbs
Bongkal	Fed. Malay States	832 grains
Bouw	Sumatra	[illegible]096.5 sq. metres
Bu	Japan	0.12 inch
Bushel	British Empire	1.03[illegible]05 U. S. bu
Caffiso	Malta	5.[illegible] gals
Candy	India (Bombay)	560 lbs
"	India (Madras)	500 lbs
Cantar	Egypt	99.05 lbs
"	Morocco	11[illegible] lbs
"	Turkey	124.45 lbs
Cantaro	Malta	175 lbs
Carat, metric	World	3.086 grains
Catty	China	1.333⅓ lbs
"	Japan	1.3[illegible] lbs
"	Java, Malacca	1.36 lbs
"	Siam	[illegible] lbs
" (tael)	Siam	1.3[illegible] lb
"	Sumatra	[illegible] lbs
Centaro	Central America	4.[illegible]031 gals
Centner	Brunswick	11[illegible].5 lb
"	Bremen	1[illegible]5 lbs
"	Denmark, Norway	110.23 lb
"	Prussia	113.[illegible] lbs
"	Sweden	93.[illegible] lb
"	Double or metric	[illegible] lbs
Chetvert	Russia	[illegible]57 bu
Ch'ih	China	[illegible] inches
" (metric)	China	1 meter
Cho	Japan	[illegible]451 acres
Coomb	England	4.1[illegible]8 bu
Coyan	Siam	[illegible]4[illegible]5 lbs
Cuadra	Argentine Republic	4[illegible] acres
"	Paraguay	[illegible] yds
" (sq.)	Paraguay	1.8[illegible] acres
"	Uruguay	1.8[illegible] acres
Cubic meter	Metric	35.3 cu. ft
Cwt. (hundredweight)	British	112 lbs
Dessiatine	Russia	[illegible] acres
Drachma (new)	Greece	15.432 grains (1 gram)
Fanega (dry)	Ecuador, Salvador	1.5745 bu
"	Chile	[illegible]8 bu
"	Guatemala, Spain	1.5[illegible] bu
"	Mexico	[illegible]5716 bu
" (double)	Uruguay	[illegible]776 bu
" (single)	Uruguay	3.888 bu
"	Venezuela	3.334 bu
" (liquid)	Spain	16 gals
Feddan	Egypt	1.04 acres
Frail (raisins)	Spain	50 lbs
Frasco	Argentine Republic	[illegible]5098 liq. qts
"	Mexico	2.5 liq. qts
Frasila	Zanzibar	35 lbs
Fuder	Luxemburg	[illegible]64.18 gal
Funt	Russia	0.90[illegible]8 lb
Gallon	British Empire	1.20032 U. S. gal
Garnice	Poland	1.0567 gal
Gram	Metric	15.432 grains
Hectare		2.471 acres
Hectolitre, Dry		2.838 bu
" Liquid	"	26.418 gals
Jarib	Persia (New)	2.471 acres
Joch	Austria	1.422 acres
	Hungary	1.067 acres
Ken	Japan	5.97 feet
Kilogram (kilo)	Metric	2.2046 lbs
Kilometre		0.62137 mile
Klafter	Austria	2.074 yds
Koku	Japan	5.119 bu
Kwamme	Japan	8.2673 lbs
Last	Belgium, Holland	85.134 bu
"	England	82.56 bu

Denominations	Where Used	American Equivalents
Last	Germany	2 metric tons (4,409 lbs.)
	Prussia	112.29 bu
Land	Scotland, Ireland	82.564 bu
League (land)	Paraguay	4,633 acres
Li	China	1,890 ft
Libra (lb.)	Argentine Republic	1.0128 lbs
	Central America	1.014 lbs
	Chile	1.014 lbs
	Cuba	1.0143 lbs
	Mexico	1.01467 lbs
	Peru	1.0143 lbs
	Uruguay	1.0143 lbs
	Venezuela	1.0143 lbs
Litre	Metric	1.0567 liq. qts
	Metric	[illegible]908[illegible] dry qts
Livre (lb.)	Greece	1.1 lbs
	Guiana (Dutch)	1.[illegible]8[illegible] lbs
Load (timber)	England	[illegible] cu. ft
Lumber, std.	in Europe	165 cu. ft (= 1,980 ft. b. m.)
Manzana	Nicaragua	1.74 acres
	Costa Rica, Salv'r, Pr.	1.[illegible] acres
Marc	Bolivia	[illegible]507 lb
Maund	India	8[illegible].2[illegible] lbs
Metre	Metric	39.37 inches
Mil	Denmark	4.68 miles
(geographic)	Denmark	4.61 miles
Milla	Nicaragua	1.15[illegible] miles
	Honduras	1.1493 miles
Mina (old)	Greece	2[illegible]0[illegible] lbs
Morgen	Prussia	[illegible]63 acre
Oke	Egypt	[illegible]8[illegible] lbs
(Ocque)	Greece	2.82 lbs
	Turkey	2.8[illegible]8 lbs
Pic	Egypt	[illegible]3 inches
Picul	Borneo & Celebes	135.[illegible]4 lbs
	China	133⅓ lbs
	Java	136.16 lbs
	Philippine Islands	139.44 lbs
Pie	Argentine Republic	0.94[illegible]05 foot
	Spain	[illegible]91416 foot
Pik	Turkey	[illegible] inches
Pood	Russia	36.113 lbs
Pund (lb.)	Denmark	1.102 lbs
Quart	British Empire	1.20032 liq. qt
		1.03205 dry qt
Quarter	Great Britain	8.25[illegible] bu
Quintal	Argentine Republic	101.[illegible]8 lbs
	Brazil	1[illegible]4 lbs
	Castile, Peru	101.43 lbs
	Chile	101.41 lbs
	Mexico	101.4[illegible] lbs
	Metric	[illegible]46 lbs
Rottle	Palestine ... South	[illegible] lbs
Sack (flour)	England	280 lbs
Sagene	Russia	[illegible] feet
Salm	Malta	8.2 bu
Se	Japan	0.[illegible]451 acre
Seer	India	[illegible]5 lbs
Shaku	Japan	11.9[illegible]3 inches
Sho		1.91 liq. quarts
Skalpund	Sweden	0.937 lbs
Stone	British	14 lbs
Sun	Japan	1.193 inches
Tael (Kuping)	China	575.64 grs. (troy)
Tan	Japan	0.25 acre
Tchetvert	Russia	[illegible]96 bu
To	Japan	[illegible] pecks
Ton	Space measure	40 cu. ft
Tonde (cereals)	Denmark	3.9[illegible]80 bu
Tonde Land		1.36 acres
Tonne	France	2,204.6 lbs
Tsubo	Japan	35.58 sq. ft
Tsun	China	1.26 inches
Tunna (wheat)	Sweden	4.5 bu
Tunnland		1.22 acres
Vara	Argentine Republic	34.[illegible] inches
	Costa Rica, S'lv'd'r	32.913 inches
	Guatemala	3[illegible]90[illegible] inches
	Honduras	3[illegible]953 inches
	Nicaragua	3[illegible] inches
	Chile and Peru	32.913 inches
	Cuba	33.380 inches
	Mexico	3[illegible]902 inches
Vedro	Russia	2.[illegible] gals
Verst		0.663 mile
Vloka	Poland	41.50 acres
Wey	Scotland & Ireland	41.282 bu

WEIGHTS AND MEASURES

Metric System

LENGTHS

Millimeters (mm)	Centimeters (cm)	Decimeters (dm)	Meters (m)	U. S. Equivalent	British Imperial Equivalent
1	0.1	0 01	0.001	0.0393700 inch	0.03937011 inch
10	1	.1	.01	0.393700 inch	0.3937011 inch
100	10	1	.1	3.93700 inches 0.3280833 foot	3.937011 inches 0.3280843 foot
1000	100	10	1	39.3700 inches 3.280833 feet	39.37011 inches 3.28084 feet

Meters (m)	Dekameters (dkm)	Hectometers (hm)	Kilometers (km)	U. S. Equivalent	British Imperial Equivalent
1	0.1	0.01	0.001	1.093611 yards 0.198838 rod	1.09361425 yards
10	1	.1	01	10.93611 yards 1.98838 rods	10.9361425 yards
100	10	1	1	19.8838 rods	109 361425 yards
1000	100	10	1	0.62137 mile	0.62137 mile

1 millionth micron ($\mu\mu$) = 10^{-12} meter = 10^{-10} centimeter = 0.01 Angstrom units

1 Angström unit or Angstrom (A U or A) = .0000000001 or 10^{-10} meter

1 milli-micron or micro millimeter (mμ) – one one-thousandth micron – 10^{-7} centimeter 10 Angstrom units

1 micron (μ) .001 millimeter = 10^{-6} meter = 10^{-4} centimeter - 10,000 Angstrom units 0 00003937 in.

1 myriameter = 10,000 meters = 6.2137 mi.

AREA

Sq. Millimeters (mm^2)	Sq. Centimeters (cm^2)	Sq. Decimeters (dm^2)	Sq Meters, Centares (m^2, ca)	U. S. Equivalent	British Imperial Equivalents
1	0.01	0.0001	0.000001	0.00155 sq. in.	0.001550 sq in.
100	1	01	.0001	0.154999 sq. in.	0.155001 sq. in.
10,000	100	1	.01	15.4999 sq. in.	15 5001 sq in.
1,000,000	10,000	100	1	10 76387 sq ft.	10 76390 sq ft.

Sq. Meters, Centares (m^2, ca)	Sq. Dekameters Ares (dkm^2, a)	Sq. Hectometers Hectares (hm^2, ha)	Sq. Kilometers (km^2)	U. S. Equivalents	British Imperial Equivalents
1	0.01	0.0001	0.000001	0.039537 sq. rod	1.1960 sq. yds
100	1	.01	.0001	0.02471 acre	119.60 sq. yds.
10,000	100	1	.01	2.471 acres	2.4711 acres
1,000,000	10,000	100	1	0.3861006 sq. mile	

VOLUME

Cu. Millimeters (mm^3)	Cu. Centimeters (cm^3, cc)	Cu. Decimeters (dm^3)	Cu. Meters (m^3)	U. S. and British Equivalents
1	0.001	0.000001	0.000000001	0.0000610 cu. inch
1000	1	.001	.000001	0.0610 cu. inch
1,000,000	1000	1	.001	61.024 cu. inches
1,000,000,000	1,000,000	1,000	1	35.315 cu. feet 1.3080 cu. yards

1 stere = 1 cubic meter

Metric System (*Continued*)

CAPACITY

1 liter is the volume of pure water which, at 4° C. and 760 mm. pressure, weighs 1 kilogram. 1 liter = 1.000027 cubic decimeter = 1,000.027 cubic centimeters.

Millimeters (ml)	Centiliters (cl)	Deciliters (dl)	Liters (l)	U. S. Equivalents	British Imperial Equivalents
1	0.1	0.01	0.001	16.231 minims 0.0610 cu. inch	0.0610 cu. inch
10	1	.1	.01	2.70518 fl. drams	0.070 gill
100	10	1	.1	3.38147 fl. ounces	0.176 pint
1000	100	10	1	270.518 fl. drams 33.8147 fl. ounces	1.75980 pints

Liters (l)	Dekaliters (dkl)	Hectoliters (hl)	Kiloliters (kl)	U. S. Equivalents	British Imperial Equivalents
1	0.1	0.01	0.001	1.05671 liq. quarts 0.264178 gallon 1.8162 dry pints 0.9081 dry quart	.2200 gallon
10	1	.1	.01	18.162 dry pints 9.081 dry quarts 1.13513 pecks 2.8378 bushels	2.200 gallons
100	10	1	.1		
1000	100	10	1		3.437 quarters

MASS

Milligrams (mg)	Centigrams (cg)	Decigrams (dg)	Grams (g)	U. S. Equivalents	British Imperial Equivalents
1	0.1	0.01	0.001	0.015432356 grain	0.01543236 grain
10	1	.1	.01	0.15432356 grain	0.1543236 grain
100	10	1	1	1.5432356 grains 15.432356 grains	1.543236 grains 15.43236 grains
1000	100	10	1	0.5643833 dram av. 0.03527396 ounce av.	0.564383 dram av. 0.0352739 ounce av.

Grams (g)	Dekagrams (dkg)	Hectograms (hg)	Kilograms (kg)	U. S. Equivalents	British Imperial Equivalents
1	0.1	0.01	0.001	0.771618 scruple 0.2572059 dram apoth. 0.03215074 ounce apoth. 0.0022046 pound av.	0.77162 scruple 0.64301 pennyweight 0.03215 ounce troy
10	1	.1	.01	5.643833 drams av.	5.64383 drams av.
100	10	1	.1	3.527396 ounces av. 2.204622341 pounds av.	3.52739 ounces av.
1000	100	10	1	2.6792285 pounds Troy or apoth.	2.2046223 pounds av.

1 kilogram = 15432.35639 grains = 0.00110231 short ton = 0.00098421 long ton.
1 metric carat = 200 milligrams = 3.0864712 grains.
1 myriagram = 10000 g. = 10 kg. = 22.04622 pounds av.
1 quintal (metric) = 100 kg. = 220.46 pounds av.
1 millier or tonne = 1000 kg. = 2204.62 pounds av. = 2679.23 pounds troy = 0.98420640 long ton = 1.1023112 short tons.

PREFIXES

The prefixes mega-, meaning one million, and micro-, one millionth, are used in connection with various simple and derived units of the metric system.

WEIGHTS AND MEASURES

U. S. System

Miscellaneous Units and Equivalents

LENGTHS

The United States standard yard is defined as 3600/3937ths meter.

Inches (in.)	Feet (ft.)	Yards (yd.)	Rods (rd.)	Miles (mi.)	Metric Equivalent
1	0.08333	0.027778	0.00505051	0.000015783	2.54001 centimeters
12	1	.33333	.0606061	.000189394	0.304801 meter
36	3	1	0.181818	.000568182	0.914402 meter
198	16.5	5.5	1	.003125	5.029210 meters
63,360	5280	1760	320	1	1.60935 kilometers

1 mil = 0.001 inch = 25.4001 microns = .0254001 millimeter
1 hand = 4 inches = 10.1600 centimeters
1 span = 9 inches = 22.86005 centimeters
1 fathom (fath.) = 6 feet = 1.828804 meters
1 link (li.) = 0.66 foot = 7.92 inches = 20.11684 centimeters
1 rod (rd.) = 25 links = 5.029210 meters
1 surveyor's or Gunter's chain (ch.) = 4 rods = 100 links = 66 feet = 20.11684 meters
1 engineer's or Ramsden's chain = 100 links of one foot each = 100 feet = 30.4801 meters
1 knot or nautical mile = 1.1516 statute miles = 6080.27 feet = 1.85325 kilometers = 1′ of arc on the Earth's surface at the equator
1 British yard = 3 feet = 36 inches = 0.914399 meter
1 British inch = 2.539998 centimeters
1 British mile = 1760 yards = 1.60934 kilometers
1 furlong (fur.) = 40 rods = 220 yards = 660 feet = 201.168 meters
1 pole (British) = 5.5 yards = 5.0292 meters = approximately 1 rod
1 British fathom = 6.08 feet
1 toise = 6 Paris feet = 1.94904 meters
1 Paris foot (pied) = 12 Paris inches = 0.324839 meter
1 Paris inch (pouce) = 12 Paris lines = 2.70700 centimeters
1 Paris line (ligne) = .225583 centimeter
1 light year = 5.9×10^{12} miles = 9.5×10^{12} kilometers
1 point (type sizes) = 1/72 or 0.01389 inch
1 line = 1/12 or 0.08333 inch
1 cubit = 18 inches

AREA

Sq. Inches (sq. in.)	Sq. Feet (sq. ft.)	Sq. Yards (sq. yd.)	Sq. Rods (sq. rd.)	Acres (A.)	Sq. Miles (sq. mi.)	Metric Equivalent
1	0.0069444					6.452 sq. centimeters
144	1	0.111111				0.09290 sq. meter
1296	9	1	0.03305785			0.8361 sq. meter
	272.25	30.25	1	0.00625		25.29295 sq. meters or centares
	43560	4840	160	1	0.0015625	40.46873 ares
	27,878,400	3,097,600	102,400	640	1	2.589998 sq. kilometers

1 square mil = .000001 square inch = .000645 square millimeters
1 circular mil = area of a circle whose diameter is one mil = .000000785 square inches
1 square link = 62.7264 square inches = 404.6873 square centimeters
1 square rod (sq. rd.) = 625 square links = 25.29295 square meters
1 square chain (sq. ch.) = 16 square rods = 404.6873 square meters
1 acre (A) = 10 square chains = 4046.873 square meters

1 British square yard = 9 square feet = 0.836126 square meter
1 British square foot = 144 square inches = 9.2903 square decimeters
1 British square inch = 6.4516 square centimeters
1 square perch (British) = 30.25 square yards = 25.293 square meters
1 rood (British) = 40 square perches = 10.117 ares or square dekameters
1 acre (British) = 4 roods

VOLUME

Cubic Inches (cu. in.)	Cubic Feet (cu. ft.)	Cubic Yards (cu. yd.)	Metric Equivalent
1	0.00057870		16.387 cubic centimeters
1728	1	0.037037	0.02832 cubic meter
46,656	27	1	0.765 cubic meter

U. S. System (*Continued*)

1 board foot (bd. ft.) = 144 cubic inches = 2359.8 cubic centimeters
1 cord = 128 cubic feet = 3.625 cubic meters
1 British cubic foot = 1728 cubic inches = 0.028317 cubic meter
1 British cubic yard = 27 cubic feet = 0.76455 cubic meter
1 cubic foot = 6.229 British gallons = 7.481 U. S. gallons
1 cubic yard = 168.17 British gallons

CAPACITY LIQUID MEASURE

Gills	Pints (pt.)	Quarts (qt.)	Gallons (gal.)	Cubic Inches	Metric Equivalent
1	0.25	0.125	0.03125	7.21875	118.292 milliliters
4	1	0.5	0.125	28.875	0.473167 liter
8	2	1	0.25	57.75	0.946333 liter
32	8	4	1	231	3.785332 liters

1 gill = 4 fluid ounces = 1.18 deciliters
1 gallon (U. S.) of water at 15° weighs about 8.337 pounds av. or 3.782 kilograms = 0.83268 British gallon
1 hogshead = 63 gallons
1 firkin = 9 gallons = 34.06799 liters
1 tun = 252 gallons
1 British gill = 1.42 deciliters
1 British pint = 4 gills = 0.568 liter
1 British quart = 2 pints = 1.136 liters
1 British gallon = 4 quarts = 277.3 cubic inches = 0.160 cubic foot = 4.5459631 liters
1 British gallon of water at 15° C. weighs 10 pounds = 1.20094 U. S. gallons

APOTHECARIES' FLUID MEASURE

Minims (min. or ♏)	Fluid Drams (fl. dr. or ʒ)	Fluid Ounces (fl. oz. or ℥)	Pints (pt.)	Metric Equivalent
1	0.016667	0.0020833		0.0616102 milliliter
60	1	0.125		3.69661 milliliters
480	8	1	0.0625	29.5729 milliliters
7680	128	16	1	0.473167 liter

1 fluid ounce = 1.80469 cubic inches
1 gallon = 128 fluid ounces = 8 pints
1 British Imperial gallon = 8 pints = 160 fluid ounces = 4.5459631 liters
1 British fluid ounce = 8 drachms = 28.4130 cubic centimeters
1 British fluid drachm = 60 minims = 3.5515 cubic centimeters
1 British minim 0.05919 cubic centimeter

DRY MEASURE

Pints (pt.)	Quarts (qt.)	Pecks (pk.)	Bushels (bu.)	Cubic Inches	Metric Equivalents
1	0.5	0.0625	0.015625	33.6003125	0.550599 liter
2	1	0.125	0.03125	67.200625	1.101198 liters
16	8	1	0.25	537.605	8.80958 liters
64	32	4	1	2150.42	35.2383 liters

1 British peck = 2 British gallons = 554.6 cubic inches = 9.092 liters
1 British bushel = 8 British gallons = 2219.3 cubic inches = 36.37 liters = 1.03151 U. S. bushels
1 British quarter = 8 bushels = 2.909 hectoliters
1 U. S. bushel = 0.96945 British bushel

MASS

Note: Three systems are in use, —avoirdupois, troy, and apothecaries'. The grain is the same in all.

AVOIRDUPOIS COMMERCIAL

The U. S. Standard pound avoirdupois is defined as 453.5924277 grams.

Grains (gr.)	Drams (dr. av.)	Ounces (oz. av.)	Pounds (lb. av.)	Tons (short) (tn.)	Metric Equivalents
1	0.03657				0.064798918 gram
27.34375	1	0.0625			1.771845 grams
437.5	16	1	0.0625		28.349527 grams
7000	256	16	1	0.0005	453.5924 grams 0.4535924 kilogram
....	...	32000	2000	1	907.18486 kilograms

U. S. System (*Continued*)

1 pound avoirdupois is the mass of 27.692 cubic inches of water weighed in air at 4° C., 760 mm. pressure
1 short hundredweight (cwt.) = 100 pounds = 45.359243 kilograms
1 short ton = 20 short hundred weight = 2,430.56 troy pounds = 907.18486 kilograms
1 stone (British) = 14 pounds = 6.350 kilograms
1 quarter (British) = 28 pounds = 12.70 kilograms
1 long hundredweight (British) = 4 quarters = 112 pounds = 50.802352 kilograms
1 long ton (British) = 20 long hundredweights = 1016.04704 kilograms
1 long ton = 1.12000 short tons = 2722.22 troy pounds = 1.01605 metric tons
1 short ton = 0.89287 long ton = 29,166.66 troy or apothecaries' ounces = 0.90718 metric ton
1 avoirdupois pound = 1.21528 troy or apothecaries' pounds = 14.5833 troy ounces
1 avoirdupois ounce = 0.9115 troy or apothecaries' ounce

TROY WEIGHT

Grains (gr.)	Pennyweights (dwt.)	Ounces (oz. t.)	Pounds (lb. t.)	Metric Equivalents	
1	0.0416667	0.0020833		64.798918	milligrams =
				0.064798918	gram
24	1	0.05	0.0041667	1.555174	grams
480	20	1	0.08333	31.103481	grams
5760	240	12	1	373.24177	grams

1 troy pound = $\frac{5760}{7000}$ or 0.822857 avoirdupois pound = 13.1657 avoirdupois ounces
1 carat (1877) = 3.168 grains = 205.6 milligrams
1 troy ounce = 1.09712 avoirdupois ounces
1 troy pound = 0.00036735 long ton = 0.00041143 short ton = 0.00037324 metric ton

APOTHECARIES' WEIGHT

Grains (gr.)	Scruples (℈ or s. ap.)	Drams (ʒ or dr. ap.)	Ounces (℥ or oz. ap.)	Pounds (lb. ap.)	Metric Equivalents	
1	0.05000	0.016667	0.0020833		64.798918	milligrams
20	1	0.3333	0.041667	0.003472	1.2959784	grams
60	3	1	0.12500	0.010416	3.8879351	grams
480	24	8	1	0.08333	31.103481	grams
5760	288	96	12	1	373.24177	grams

TIME

Seconds (sec.)	Minutes (min.)	Hours (hrs.)	Days	Years (yrs.)
1	0.016667	0.00027778		
60	1	0.016667	0.000490196	
3600	60	1	0.041667	
86400	1440	24	1	
			365.242218	1 (common)
			365.256	1 (sidereal)

1 lunar month (mo.) = 29 days 12 hr. 44 min. 1 sidereal second = 0.99727 mean solar second

ANGLE

Seconds (″)	Minutes (′)	Degrees (°)	Circumference	
1	0.016667	0.00027778		2π radians = 360° = circumference
60	1	0.016667		π radians = 180°
3600	60	1	0.0027778	$\frac{\pi}{2}$ radians = 90°
1,296,000	12,600	360	1	$\frac{\pi}{4}$ radians = 45°

1 degree = 0.017453 radian

1 radian = 57° 17′ 44.8″ = 57.2958° = 3437.75′ = 206265″ = $\frac{1}{2\pi}$ of a circumference

1 grade = $\frac{1}{400}$ circumference = 100 centesimal minutes = 0.0157079 radian

1 centesimal minute = 100 centesimal seconds

SOLID ANGLE

1 steradian = $\frac{1}{4\pi}$ of the solid angle around a point.

When Queen Elizabeth ruled over England these were some of the weights and measures her subjects used. Though the workmanship was awkward, it was substantial and even had a kind of sturdy beauty.

Photo by Science Museum London

HOW BIG IS IT? HOW HEAVY IS IT?

Here Are All the Curious and Clever Ways That We Have Found to Weigh Things and to Measure Them

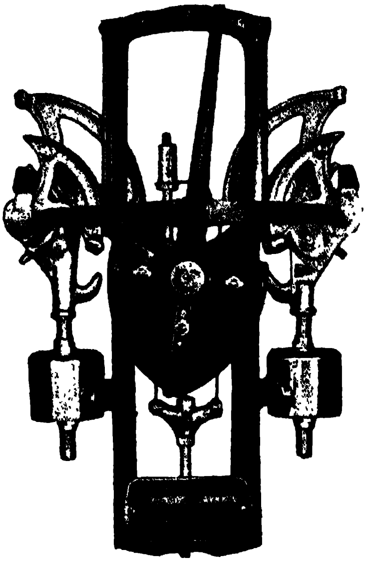
EVERY one of us has tried hard to find out which of two stones was the heavier by holding one of them out in each hand or by holding both of them out in the same hand, one after the other. And often we have found it pretty hard to tell.

Long ago our forefathers had no better way than this of finding out how heavy a thing was. In due time one of them must have hit upon the happy notion of balancing one stick across another, and of placing the two stones on the two ends of the stick. Then the stone that sank down would be the heavier, and the genius that did the trick would have invented the first rude pair of scales.

From that early day down to our own time we have gone on inventing hundreds and thousands of methods to weigh things and to measure things—for at bottom, as we are going to see, weighing and measuring are the same thing. And to this day we still have many different ways of weighing and measuring, in different countries or even in various parts of the same country. There are so many of them that they are often confusing, and all but one of them are imperfect. For we have found out only one perfect system of weights and measures, as we shall see. But first we may tell about a few of the curious systems that have grown up in the past.

Of course the weight of a thing is merely the pull of gravity from the earth upon it. But long before men knew anything about gravity they had invented very good balances for telling how much the pull was, or how much a thing weighed. All of that was done before the dawn of history. For when the curtain of history goes up, we find that the Egyptians already have good ways of weighing out supplies and other things—such as tribute money, for instance. They weighed articles by the "uten" and the "kat" just as we weigh them by the pound or the ounce.

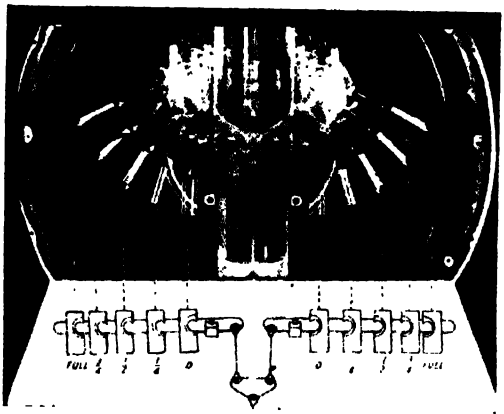
But every other nation had its own weights and measures, often of many kinds, and the situation might be very puzzling for a traveler or trader. To be sure, men had nearly always begun measuring things in about the



Automatic scales are better than beam scales or steelyards, for they use a self-operating means of balancing the load on the scale platform. It is not necessary to add weights and move poises by hand until a load is balanced; an automatic counterbalancing scale operates the instant a load is applied to it, and moves a pointer which indicates the weight on a graduated dial.

In the scale illustrated here, the counterbalancing mechanism, shown at the top of the page, consists of two "pendulum assemblies." In each of these the pendulum is part of a set of accurately made and carefully adjusted cams—devices shaped in such a way as to give, when they are moved, a peculiar motion to a mechanism with which they are in contact. The cams are so designed that the two pendulum assemblies are suspended on steel ribbons with the pendulums hanging straight down while the scale is at zero.

When a load is applied to the scale, a lever system—to be referred to later—conveys the downward force to two steel ribbons attached to the two sets of cams. As the pull is applied to these ribbons the cams turn, swinging the pendulums outward and upward until the load is counterbalanced by the pendulums—see the center illustration. As the pendulums rise to counterbalance the load, a rack, or straight rod with carefully cut teeth, turns a pinion, or small wheel geared to a larger wheel. The pinion is fastened to the weight indicator, or pointer. So as the pendulums rise the pointer moves on the dial till it comes to rest at the figure which indicates the weight of the object being weighed on the scales.



The center illustration shows how the pendulum mechanism can be compared with a beam scale. This picture shows five separate weighings on an automatic scale, and compares the pendulum motion with the positioning of poises on beams. As a load is applied to the scale, the pendulums swing out to balance the load. This action corresponds to the moving of poises by hand on a beam scale. The heavier the load on the scale the farther the pendulum swings out.

This same counterbalancing mechanism is used on automatic dial scales of all sizes, from models having a capacity of 30 pounds to motor-truck scales having a capacity of 30 tons. The main difference in the scales themselves is in the lever system which reduces the downward push of the load on the scale platform to a smaller force that can be more easily and accurately measured by the sensitive counterbalancing mechanism. The cut at the bottom of the page shows a motor-truck scale with the pit cut away to reveal a portion of the lever system. On scales of lower capacity this lever system is smaller in proportion to the capacity of the scale. A scale of this sort is very accurate and very reliable. There is little in it to get out of order, and worn parts can be easily replaced. It can work just as accurately when it is out of level as when it is level—a great advantage, since no floor is perfectly level and emplacements sag with time.

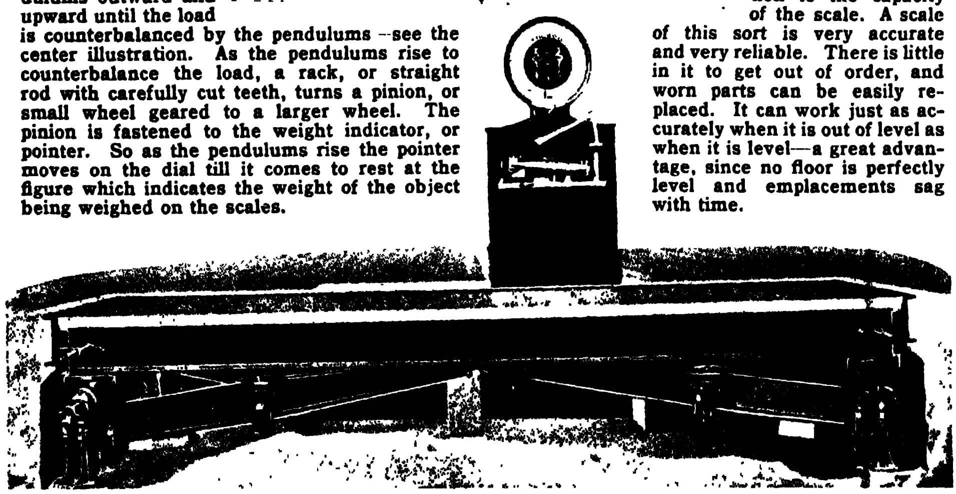


Photo by W. & T. Avery, Ltd

Two thousand years before the birth of Christ people were buying and selling down in Egypt, and keeping elaborate accounts. We have been able to learn from wall decorations a great deal about the life they led and how they did things, and we know that they weighed their goods in scales like the ones in this temple. Here, using weights cast in the form of animals, like those in the foreground, a slave is weighing gold.

same way—by comparing them with parts of their own bodies. Thus they very often measured by the "foot," as we do still, though we now call it exactly twelve inches. So they frequently used the "pace," and our own word "mile" comes from the Latin term for a thousand paces—"mille passuum"—though that was really two thousand of our paces, because a pace was one step with each foot. For other measures they took other parts of the body. Thus a cubit was the distance from the elbow to the end of the middle finger, and a span was that from the end of the thumb to the end of the little finger when the hand was spread out. And men also measured by the "finger," or the finger "nail," or the "palm" or "hand." To this very day we always say that a horse is so many "hands" high—though a hand now means four inches.

At the very start these measures were far from accurate, because the feet and hands of different men were of such different sizes. A big man always got the best of the bargain. But this trouble was soon gone. For all the men soon agreed that a stick of a certain length, or later a metal rod, should be a foot, another one a pace, and so on. These sticks or rods then became the units of measure for everybody; and thus they have come right down to our day, though we still call some of them by the names of parts of our own bodies.

Why We Write "Lb." for Pound

Of course any unit of measure that was agreed upon would do well enough for all those who used it. But there were so many units in the different lands, or even in the same land, that at the time when the Roman

empire drew all the lands together, the condition of weights and measures was a very perplexing one. So the Romans settled on a single set of units which would hold good for the whole empire—that is, all over the civilized world. They made a certain weight which they called a "libra," or "pound"—that is why we still write *lb.* for "pound"—and a certain bronze rod which they called a "pes," or "foot." These they kept carefully guarded in a Roman temple, and these were the standard pound and foot for all the Roman state. For the first time all the civilized world had a single way to weigh and measure.

But the Roman empire went to ruin, and the single way went with it. In the Middle Ages people went back to hundreds of different ways of weighing and measuring, such as they had had in older days. And we have never managed to get back to any single way since, for we still weigh and measure very differently in America, in England, and in the rest of Europe. If you asked for a "kilo" of beefsteak in Paris, have you any notion how much you would get?

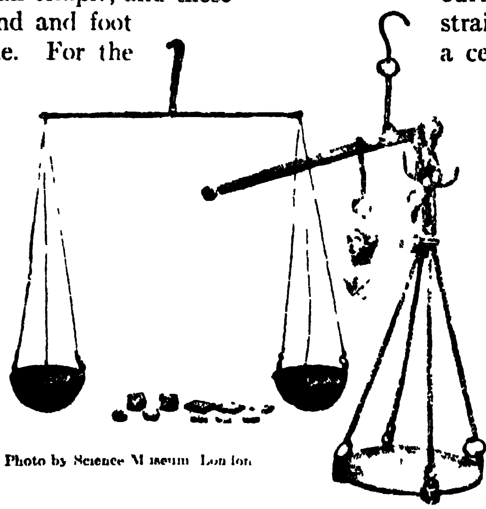


Photo by Science Museum London

Here is a Roman balance and steelyard from the first century. The steelyard, at the right, is a balance in which the two arms are not of the same length. The article to be weighed is hung on the shorter arm, and a weight is adjusted on the longer arm so that the two balance. The longer arm is marked off into a graduated scale, so that the weight may be read accurately.

When a Pound Was Not a Pound

During the Middle Ages, when every little district had its own units of weight and measure, there were a good many strange results. In one place a pound might be some thirteen ounces, in another perhaps twenty-four. In one country a foot might be twice as long as in another. On the land a mile might be shorter than on the sea, as it still is to this day. And to tell of only one other confusion, a given kind of thing might be weighed in one sort of scale, and another thing in another sort. Thus gold and certain costly things were weighed on one scale, but meat and other cheaper things upon another. And that is why we are still weighing them in different scales to-day—with the result that an ounce of gold is by no means the same weight as an ounce of salt or sugar.

Where Our Yard Came From

Little by little, however, people began to bring order out of this chaos, though often in rather curious ways—and some of the curious ways have come straight down to us. When a certain place was a great trading center, its unit of weight and measure was likely to be followed by the people for some distance around it. Such a place was Troyes, in France, and its unit, of Troy weight, has come down to our time as the standard of the jewelers. For all England a yard was fixed as the distance from the nose to the thumb of King Henry I. You may have seen your mother measure a piece of cloth the same way when she had no yardstick at hand. And in England the parliament settled certain measures of weight and length by so many grains of wheat and barley. Thirty-two grains of wheat made one pennyweight, and three barleycorns laid in a row made an inch. Our way of numbering the sizes of shoes to-day goes back to the rude old method of measuring by barleycorns.

What an English "Stone" Weighs

There were many other kinds of measures in England. When a man stretched out his arms on both sides, the distance from finger tip to finger tip made a "fathom." And the sailor still measures the depth of the sea in fathoms, though a fathom is now always six feet. Then there was the "ell" for measuring cloth—the name came from the word for "elbow," but the measure was forty-five

inches long in England, though of various other lengths in other countries. For only one more instance, there was the "stone," which is still used in England for weighing men and horses. For in England to-day no one would ever say a man weighed 160 pounds, but 11 stone, 6—a "stone" being fourteen pounds.

And when it came to measuring liquids in old England, matters were still worse. There were some eight or ten measuring vessels to choose from. Of those only the gallon is left to-day, with its divisions into quarts and pints and gills. But even to-day there are two kinds of gallon; the English one holds ten pounds of water, while the American one, since 1707, has held only eight. And likewise there are two kinds of ton, one weighing 2,000 pounds and the other the "long" ton— weighing 2,240.

Now if this used to be the state of things in England, we can imagine the confusion all over the rest of Europe, with each country using its own system or systems of weights and measures. We have talked mainly about the English ones because our own have all come down, with some slight differences, from them. Our own weights and measures are still very curious and irregular. They still have many features of the confusion that has come straight down from the Middle Ages. A few examples, known to everyone, will show the fact.

Photo by W. & T. Avery Ltd

If you had lived in England in the year 800, a fish peddler like this one would have come to your door and weighed out his wares with a curious steelyard that he held in his hand. It had no movable weights; but the ring by which it was held could be slipped back and forth, and on the beam spaces were marked off by nails driven into the wood. So the weight of an object could be judged by the number of nails between the end of the beam on which the object hung and the spot at which the ring had to be held in order to keep the beam straight.

How We Weigh and Measure

Thus *twelve* inches make a foot, *three* feet make a yard, *five and a half* yards make a rod, *forty* rods make a furlong, and *eight* furlongs make a mile—which is 1,760 yards or 5,280 feet — and *three* miles make a league. What a lot of figures to remember.

So much for measuring distance. In measuring area we are no better. It takes 144 square inches to make a square foot, 9 square feet make a square yard, 30¼ square yards make a square rod, 160 square rods make an acre, and 640 acres make a square mile.

In solid measure 1,728 cubic inches make a cubic foot, 27 cubic feet make a cubic yard, and 128 cubic feet make a cord.

In what we call dry measure, 2 pints make a quart, 8 quarts make a peck, and 4 pecks make a bushel. In liquid measure 4 gills (jĭl) make a pint, 2 pints make a quart, 4 quarts make a gallon, 31½ gallons make a barrel, and 2 barrels make a hogshead.

To cap it all, we have two kinds of weight. In Troy weight, as used by the jeweler, 24 grains make a pennyweight, 20 pennyweights make an ounce, and 12 ounces make a pound. But in avoirdupois (ăv′ẽr-dŭ-poiz′), as used by the grocer and others, 437½ grains make an ounce, 16 ounces make a pound, and 2,000 pounds make a ton--unless it is a "long" ton! And then the apothecary (ȧ-pŏth′ē-kâ-rĭ), or druggist, uses a kind of weight that is still a little different.

How We Count Our Money

Now we learn all this in school, and then nearly all of us forget a good deal of it. But nobody ever forgets that ten mills make one cent, ten cents make one dime, ten dimes make one dollar, and ten dollars make one eagle. The reason is merely that our coinage

is regular, while our weights and measures are still highly irregular. There is no rule at all about them.

The Only Perfect Way to Measure

Nearly a hundred and fifty years ago the king of France decided to have one rule for them all. He chose a committee of French scientists to make the rule; and because he wanted a single rule for all the world, he invited the other nations to send their scientists too.

And they might all have come together and agreed but for one trouble. At that moment the French Revolution broke out. In a short time there was no king left in France, and it was none too safe for scientists to go there Yet the French scientists went on with their work as best they could, and in due time they made up one single rule for all weights and measures. It is the one perfect system that we mentioned a while ago, the only one the world has ever seen.

The famous London Stone rested behind this iron grill in the wall of St. Swithin's church in London for many years until the church was bombed in World War II. This was the stone the Romans are supposed to have used as a center from which to measure distances when they ruled Britain.

It was no easy thing to make, as we shall see if we think about it just a moment. The scientists had to find a single unit by which they could measure every kind of thing in the world, and also weigh every kind of thing. It had to be a unit to measure the length of a line across a room or across a city, around a tree or around the earth, or from the earth to the North Star. With this same unit they must also measure the area of a city lot, or of the land of France; and with it they must furthermore measure the volume of any object—a pebble or a mountain, a pail of water or a lake or ocean.

And with this same unit, finally, they must be able to *weigh* everything in the universe—from salt and sugar to the sun and moon. Now how could they find one unit in which to tell the distance to the moon, the area of the moon, the volume of the moon, and even the weight of the moon? When we have answered that, we shall see that measuring and weighing, as we said before, are really the same thing.

But before we answer we must face one other trouble. The very unit that we use, whatever it is, will never stay exactly the same. A metal yardstick is a little longer, as everybody knows, in the sunshine than in the shade, in any warm place than in any cold place because "heat expands and cold contracts." Anything that weighs a pound at the Equator will weigh a little more as we take it north or south; for since the earth is flattened toward the poles, the thing will be a little nearer to the center of the earth, which will therefore pull a little harder on it For the same reason, it will weigh a bit more at the seashore than on a mountain. And it will even be a little smaller, especially if it is a soft thing, at the seashore; because the pressure of the atmosphere is greater there, to press it together. Everybody knows that water gets bigger when it freezes, for it bursts the strongest pipes in the house. So once we have decided on our single unit, we have to find some way to keep it from changing size and weight right under our eyes.

All of these troubles the scientists mastered. Let us see how they did it.

What Is a Meter?

First they took the distance from the North Pole to the Equator, on a line running through Paris. Then they divided this into ten million parts. One of these parts they

called a meter, or "measure"; and this meter, which would always be the same, became their unit. The meter is a little longer than our yard; it is 39.37 of our inches.

For shorter measurements they divided the meter by tens—or used the decimal system, so easy to remember in our coinage. Every meter has ten decimeters, a hundred centimeters, a thousand millimeters. For longer things they multiplied the meter by tens. Ten meters made a dekameter, a hundred meters made a hectometer, and a thousand meters made a kilometer. Whenever they divided they did it in Latin, and whenever they multiplied, to make things easier they did it in Greek. Thus "millimeter" is Latin for "a thousandth of a meter," while "kilometer" is Greek for "a thousand meters"—or .621 mile— and so on with the other terms.

The picture at the left was based on a scene in a fifteenth century window of stained glass in the cathedral at Tournai. It shows a big pair of scales in use in a French warehouse.

Photos by W. & F. Avery, Ltd

Here gold and silver plate is being weighed in a shop in London at the end of the eighteenth century.

Next it was easy, of course, to use this same meter for square surface, or area, and for cubic contents, or volume. A sheet of paper would simply be so many square decimeters, and the whole country of France so many square kilometers; a pebble would be so many cubic decimeters, and the moon so many cubic kilometers.

Then instead of pints and pecks they made a measure, for liquids especially, out of the same system. They took a cubic vessel exactly ten centimeters on each side, or a thousand cubic centimeters in volume. The amount of water that this vessel would hold was the unit. This they called a liter (lē'tẽr). So one thousand cubic centimeters of water made a liter—about one quart. And this they divided by tens into deciliters, centiliters, millimeters; and multiplied by tens into dekaliters, hectoliters, and kiloliters—words which explain themselves.

But these are all measures. Where do the weights come in? Well, they took the weight of one cubic centimeter of water when water is at its heaviest—just before it freezes, or at 4 Centigrade—and made that the unit. They called it a gram. So one cubic centimeter of water at this temperature weighs a gram, or .002 pounds. Then they divided the gram into decigrams, centigrams, and milligrams, and multiplied it into dekagrams, hectograms, and kilograms.

Such are the main facts about the system which French science gave the world in 1791. It is the famous "metric system"—the only scientific way of measuring and weighing that the world has ever had. Starting with the distance from the North Pole to the Equator, it gave us one invariable unit for measuring and weighing anything from a pinhead to a mountain—and even things far smaller and far larger. Yet it is so simple that anybody who can multiply by ten can learn it in five minutes and remember it forever.

It is now used in nearly every civilized country in the world except England and America. Even in these lands the scientists always employ it, and certain business men are trying to introduce it, for it is vastly more convenient and so would save time and money. Some day we shall surely come to it; but "the march of the human mind," as Edmund Burke said, "is slow."

Reading Unit No. 5

ALL THE WAYS OF KEEPING WARM

Note: For basic information not found on this page, consult the general Index, Vol. 15.

For statistical and current facts, consult the Richards Year Book Index.

Interesting Facts Explained

Things to Think About

What is the main trouble with the hot-air system?

Why do we use thermostats?

What happens to most of the heat from the fires in the fireplaces?

Why is electric heating for our homes not more popular?

Picture Hunt

Related Material

Leisure-time Activities

PROJECT NO. 1: Make a model of an early fireplace, 10-380-81

PROJECT NO. 2: Build a model of a hot-air heating system, 10-383

Summary Statement

Our ancestors could not live in many parts of the earth because of the intense cold, but we can live in comfort almost anywhere because we have learned how to heat our buildings.

Photo by Field Museum

The home of these simple cave men was the place where they built their fire. The father might roam at will in the warm sunshine, hunting deer or bison. But at nightfall the world grew cold. Clad only in a few skins and at the mercy of his deadly enemy the saber-toothed tiger, he then fled to the shelter of his cave. But even here the cave bear might hunt him out, and besides, the rock was damp and cold. So he built a fire to scare the wild beasts away and give him a little warmth—and even more smoke!

ALL *the* WAYS *of* KEEPING WARM

From a Bonfire for a Few Persons, We Have Come to a Furnace for Many Thousands. But How Warm Do You Think You Ought to Be?

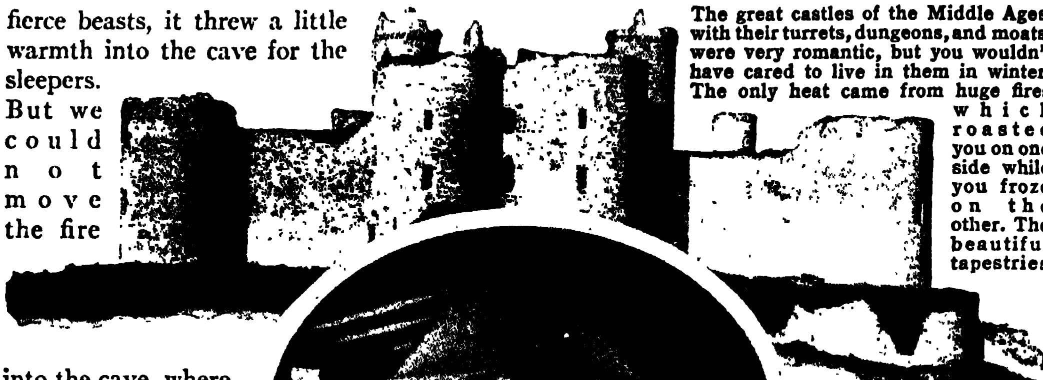
THERE was once a time when we had no heat at all except what the sun sent down to us, for we knew no way of making any other kind. In that day there were many parts of the earth on which we could not live, and even where we could live it was often much too warm in daytime and in summer, and pretty chilly in the night or during winter.

Now we have learned how to keep warm enough to live almost anywhere in the world. For that reason we can live in far more different places than any other large animal can survive in. And this is the story of the various ways that we have found of keeping warm, and so of spreading all over the earth.

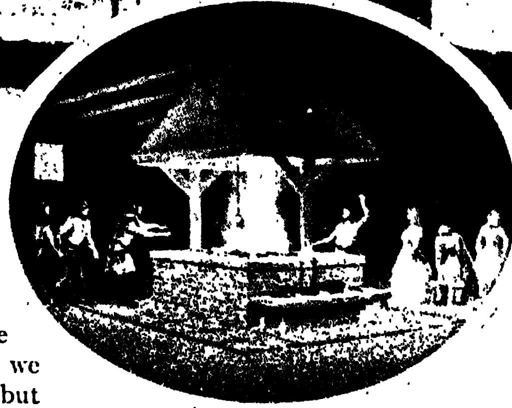
The first heat we made came from an open blaze on the ground, as has been told in our story about fire. For many a century that was the only kind of heat we knew how to make; and it is still a very pleasant way to keep warm at certain times, as on a chilly night when we are camping out.

But long ago we stopped living out of doors. When we were still dwelling in caves, we used to have a big fire at the mouth of our cave at night. Besides keeping off the

fierce beasts, it threw a little warmth into the cave for the sleepers. But we could not move the fire



The great castles of the Middle Ages, with their turrets, dungeons, and moats, were very romantic, but you wouldn't have cared to live in them in winter. The only heat came from huge fires which roasted you on one side while you froze on the other. The beautiful tapestries which covered the walls kept out only part of the drafts; and often there was no glass in the windows, since glass was so rare and valuable in the early days that the lords who owned it took it with them from castle to castle wherever they moved.



Photos by L. M. & S. Ry., Metropolitan Museum of Art, and G. W. R. Ry.

into the cave, where it would do the most good, because we should have choked with the smoke.

Then when we started living in a house of one sort or another, we had no way to heat it but to burn a fire inside it. So what about the smoke? Well, we did the best we could about it. We left a big hole in the roof or in the wall for the smoke to get out. Then about the year 1100 A.D., when the first chimney came into use, we got something better. We no longer had to choose between freezing rooms and rooms choked with smoke from a fireplace.

With a chimney over the fireplace we could finally be fairly comfortable. Of course we had to have a separate fire in every room,

Photo from Philip D. Gendreau

This wonderful old kitchen fireplace is in Sulgrave Manor house, the home of George Washington's English ancestors. The house may have been built soon after chimneys began to be common. To celebrate one hundred years of peace between Britain and America, the house was bought in 1914 and made into a shrine.

and it took a good deal of work to keep the fires going. They were more likely to set our house ablaze. And at best we lost most of the heat we made, for more than three-quarters of it went up the chimney.

In the Old World to this day most of the rooms are heated by a fireplace or grate. That is the most cheerful way to warm a room. So in America we often have fireplaces simply for their cheer. Even when we get our heat from the steam radiator, we love to watch the blaze and the glowing coals, just as our fathers used to do long ago.

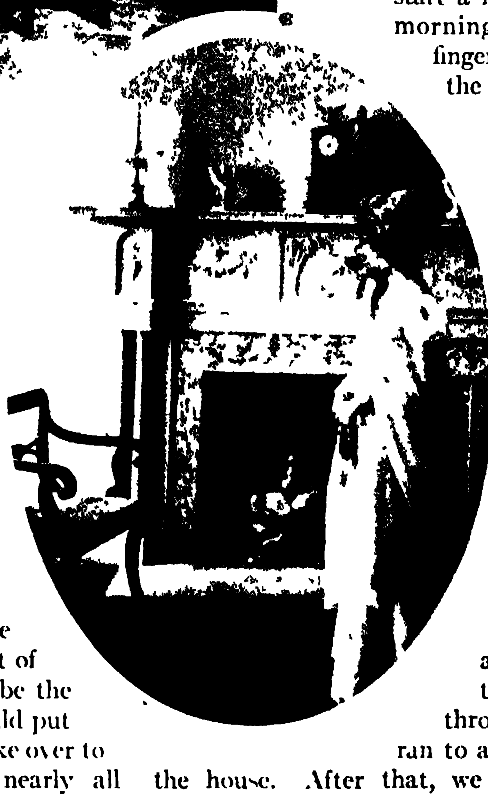


Photo by Metropolitan Museum of Art

The fireplace above was a real necessity to the housewife sitting beside it, for besides furnishing heat to the house it was the only place where she could cook the family meals. But the lady of fashion below thought of her fireplace only as a cheerful place around which to group her friends when they came to call.

Three-quarters of our heat kept going straight up the chimney. Could we somehow move the fire away from the chimney, into the middle of the room, and save most of the heat? Yes, but there would be the smoke again. But maybe we could put up a sort of pipe to carry the smoke over to the chimney without carrying nearly all the heat too. Suppose we build a sort of box for our fire in the middle of the room — we can make it out of iron— and run a pipe from the box to the chimney?

It took a big man to have an idea like that, and Benjamin Franklin was the man. He made the first real stove. So it is less than two centuries since we have had stoves, and for a long time they were called "Franklins."

Now with a stove we saved far more of the heat we made, and had it in the middle of the room, warming all the parts about equally. We could sit all around it. Many a reader of these words is toasting his toes by a stove as he runs through them. But still a stove may be an ugly thing, and a rather dirty thing; and it is always in the way, right in the center of the family. We also have to have a stove in every room—and what a job to get out the ashes and start a new fire in the morning when your fingers are blue with the cold!

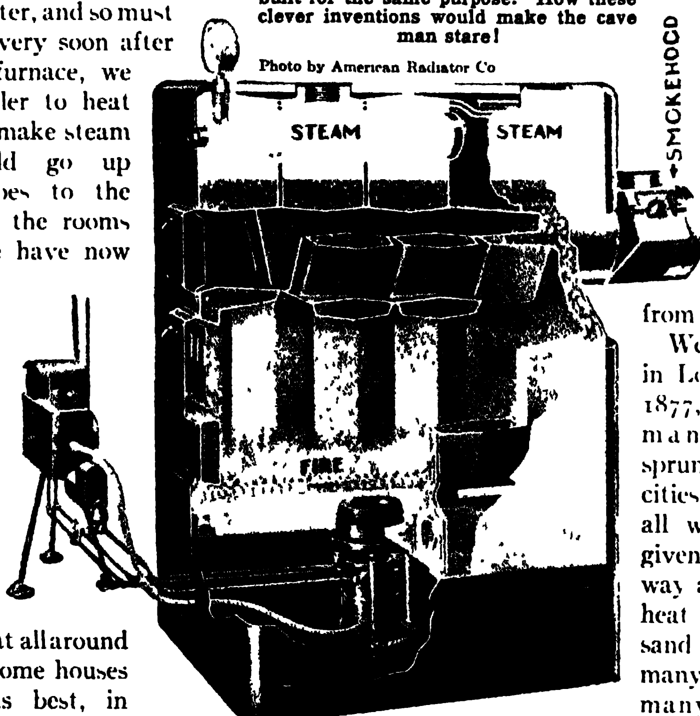
For these reasons some one had the happy notion, a little over a hundred years ago, of putting one big stove down in the cellar. He built a great jacket around it to hold the air it heated, and brought up the hot air through pipes that ran to all the rooms in the house. After that, we had only one fire to keep going, and it was out of the way. It was a big fire and would go all night long; once it had been started in the autumn, it need never be kindled again all winter; and it would heat all the rooms more evenly than the old stoves upstairs. It would get

good fresh air through a big pipe from outdoors, heat it, and send it on up to us; for hot air has to rise, as we all know.

The Furnace Goes to the Cellar

So now we have a furnace. And many is the house to-day, in many a land, that is warmed by a furnace in the cellar sending up hot air through a "register" in each room.

Now if hot air must rise, so must hot water, and so must steam. So very soon after we had a furnace, we made a boiler to heat water or to make steam which could go up through pipes to the radiators in the rooms above. We have now reached the point where we never need to see the fire. Down beneath the ground we heat something that will flow and make it carry the heat all around for us. In some houses warm air is best, in some hot water, and in others steam. But steam is by far the best in large buildings. It is found in nearly all of them to-day.



This is a modern oil-burning furnace. As the water is heated, it rises and turns into steam, which is then sent through pipes to warm the various rooms in the house. Coal-burning furnaces are also built for the same purpose. How these clever inventions would make the cave man stare!

Photo by American Radiator Co

How Central Heating Works

There are several systems for carrying the steam through a house, but they are all alike in principle. The steam comes up through a pipe into the radiators. As it cools, it turns into water again. Then it goes down the same pipe, or another one, to be made into steam once more—unless the boiler is very far away, when it may be better to save piping by running the returning water into the sewer and using a fresh supply for the next steam. These methods of heating are known as central heating systems.

But how can the boiler be very far away? Well, it is far enough when we are heating a building seventy-five stories high. But often it is very much farther. For as soon as we got well used to heating all the rooms in a house with one fire, we began to think of heating all the houses of a group in the same way all the different buildings of a great mill, for instance, or of a large university. And if we can do that, why not heat a whole section of a city from a single center?

We began to do that in Lockport, N. Y., in 1877, and since then many plants have sprung up in American cities to supply heat to all who want it in a given district. In this way a single plant may heat a hundred thousand people, or even many more. There are many advantages in such a system. The fire and smoke and ashes are hidden away where no one sees them. The steam comes under the ground in pipes that may be a mile long. It rises to our home or office just as the gas and water do. And we turn on the heat as easily as we turn on a light while a little meter keeps a record of how much we use and must pay for. We may even cook with the steam if we like.

The pipes that bring the steam so far have to be carefully laid. As we know, everything gets bigger, or expands, as it gets warmer. A hundred feet of pipe with steam in it would crumple up unless there were room for it to lengthen. So we have to make in the pipes neat expansion joints

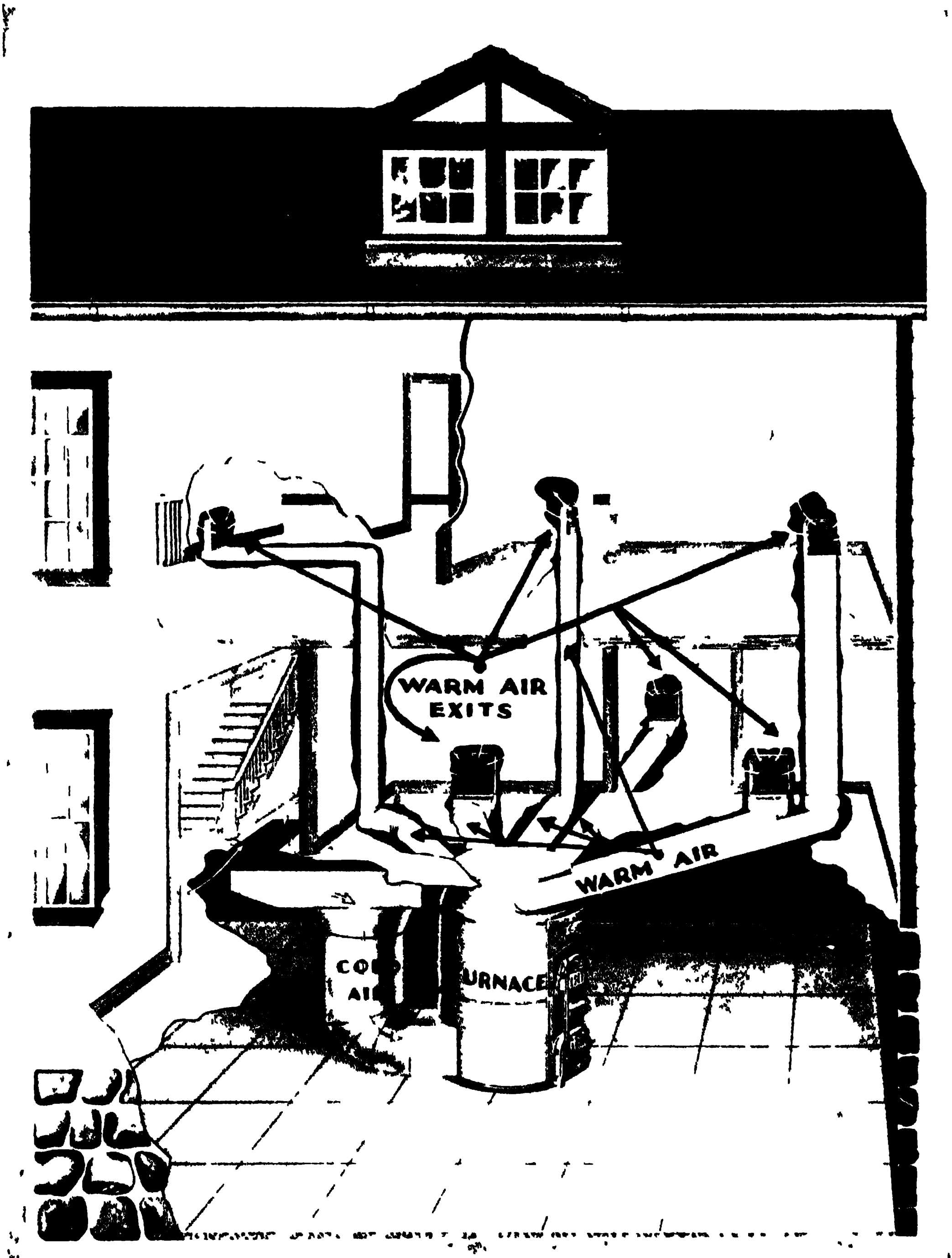


Photo by the Fox Furnace Co

If you have read about the winds and air currents, you will remember that the air which has been heated in the warm regions around the Equator rises and sweeps north and south toward the colder parts of the globe. Then as it cools, it sinks down again and blows inward to the Equator, where it is reheated and goes through the process all over again. Men, in heating their houses with a hot-air system, are following Nature's example. Air pipes go through the furnace, which, like the equatorial regions, heats the air so that it rises and passes through other pipes to the rooms. Then, when the air cools, it flows down again.

that will let them grow longer or shorter without breaking up or losing the steam.

Of course a heating system also supplies us with hot water an important item.

And now we have come all the way from a bonfire on the open ground to a steam radiator that can bring us heat from a mile away. But still we have only one way to make the heat in the first place. We have to burn something. For many a century we never dreamed of burning anything but wood. Then we found a coal fire to be hotter and more lasting. Now we burn a great deal of oil and gas. Gas may be natural or manufactured on other pages we tell how it is made. Natural gas is sometimes piped thousands of miles to a city.

So our progress has been of two kinds—in finding more things to burn, and more ways to carry the heat where we wanted it. As we have turned it into steam, we can even turn it into gas or electricity if we want to. But it is pretty costly to heat a house with electricity, though a small electric heater in a given room is often very useful. And it is bad to heat with gas unless the gas fire is in an open chimney. For burning gas, like any other burning thing, eats up the oxygen in the air; so we ought to send the bad air right up the chimney after using it, and let in good air instead.

Air That Poisons Us

Now that brings us to another point. When we used to sit around a bonfire, we had only one problem—to keep the air around us warm. As soon as we were living indoors, we had two—to keep it warm and to keep it clean at the same time.

In an air-tight room we might have heat enough to be snug and yet die in a little while for lack of oxygen. For every time we breathe we take some oxygen out of the air and put some carbon dioxide (dī-ŏk′sīd) into it; and when this has gone far enough, the air will poison us. So the only way to keep living is to keep changing the air in our room, and the only way to be well and strong is to see that it changes rapidly. For not only do our lungs need clean air to keep us from such dread disases as tuberculosis; our skins need it even more. Have you ever seen a hot room full of people, all fidgeting because the air was so dry and stale? Do you remember how nice it felt to get outdoors again? That was because your skin, even more than your lungs, likes air that is fresh and moist and moving.

In any room ten feet by twelve, with a single person in it, the air ought to be changed every hour. The more persons there are in it, the oftener the air should change. In public rooms that are often crowded we have to devise special systems for altering the air. In many places the law requires that some eighteen hundred cubic feet of fresh air shall be drawn into a schoolroom every hour for each pupil there.

So we cannot just shut up a room and heat it. That would be simple enough. We must leave it open, more or less, and still heat it. We must air it, or ventilate it, as well as warm it. Every heating system should take care of ventilation too.

The fireplace and stove will do so pretty easily. They keep sending a lot of bad air up the chimney, and good air has to keep coming in through the cracks around the windows and the doors. The hot air system may give us fresh air, but not moist air. And hot water and steam do nothing to change the air at all. The air in a steam-heated room is often very stale and very dry far drier than the air in the middle of a desert.

What Is Winter Air Conditioning?

Of course we can make the air in our homes more healthful and more comfortable by just keeping a window open or by putting a little pan of water on the radiator to send its moist vapor into the air. But a modern heating system can do much better for us than that. It can provide ventilation, clean the air, and add moisture to it as well. We call this type of heating "winter air conditioning."

With winter air conditioning, as with most types of heating systems to-day, we can keep the rooms in our houses always at the same temperature by means of a thermostat. This is a thermometer that of itself turns the heat on or off whenever the temperature

gets below or above a certain point and we can set it at any given point beforehand. Since the thermostat can be placed in our living room or in any other convenient spot in the house we need not see the furnace to control the temperature. More elaborate systems make it possible for us to have different temperatures in various parts of the house. The thermostat also can take care of the ventilation.

In principle winter air conditioning is quite simple. When we need warmth in our home, air is drawn into the heating unit through filters that clean the air, removing the dust, dirt, and most of the germs that can cause colds and similar winter illnesses. Then the air is warmed, and an automatic humidifier (hū-mĭd'ĭ-fī'ēr) adds just enough moisture to the air to keep us comfortable. The warm clean moist air then passes into each room, to provide springtime weather in the house even on the coldest days. To keep us wide-awake and alert, the air is always circulating in draftless motion and is replaced by fresh air as often as four or five times an hour. As a matter of fact when moisture is added to the air we can be comfortable at lower, more healthful temperatures.

Shut the Door to the Basement!

Not long ago heating equipment was designed merely to heat our homes. Nothing was done to make it attractive to look at. In fact, by present-day standards much of it was ugly. Furnaces and boilers were installed in dark, dirty basements that were used only as storerooms. Radiators were large and elaborately decorated and took up a great deal of space. Most heating equipment was a good deal of an eyesore. We endured it only because we wanted to be comfortable.

But now all that is changed. In order that our homes may be more attractive, radiators, boilers, and winter air conditioners are more colorful and smartly designed than we should have imagined possible a few years ago. We can now play games or have a small workshop in a cheerful basement recreation room that the whole family enjoys. For brightly colored jackets on boilers and winter air conditioners lend an air of gayety to cellars that used to be ugly and forbidding. The basement is now one of the merriest rooms in the house. Upstairs, stream-lined radiators fit unobtrusively into the other rooms.

No Basements or Radiators

Many modern houses have no basement at all. Instead we are likely to find the central heater in a tiny utility room. Or it may be in the kitchen, fitting in along with the kitchen stove and other kitchen equipment and making an extra work table while it provides heat for the building.

Nor is it any longer uncommon to find homes with central heating but without radiators and registers altogether. Pipes buried in the floors or mounted in panels in the walls carry hot water, steam, or hot air, and warm the house with radiant heat. People are said to feel more comfortable at lower temperatures in a house with the heat in the floors and walls than in houses otherwise heated.

Heating without Fuel

Progress in finding new methods of heating our homes is made all the time. Solar houses, especially constructed to make use of the sun's heat, are possible even in cool or moderate climates. It is also possible to heat homes with the sun's heat that is stored in the earth or in the water of a well. This kind of heating makes use of a heat pump, run by electricity. The system works on much the same principle as the electric refrigerator. A pipe is run into the earth or into the well. Then a liquid refrigerant is circulated through it, taking the heat from the earth or water and carrying it into the house, where the liquid is put under great pressure and so made hotter. As it passes through pipes it warms the air around them and, in turn, heats the house.

A turn of the switch will reverse this system and provide cool air for a house in summer. But other systems for winter heating may be made to cool the air and make it clean and germ-proof in summer. Many buildings have cooling systems or air conditioners that are quite separate from the heating plant. Merely forcing the air over cool water will make a house more comfortable.

Reading Unit
No. 6

HOW WE TURN NIGHT INTO DAY

Note: For basic information not found on this page, consult the general Index, Vol. 15.

For statistical and current facts, consult the Richards Year Book Index.

Interesting Facts Explained

How the cave men could see at night, 10–388-89
How skulls were used for lamps, 10–388
The first modern lamp, 10–388
Lamp oils, 10–389
How the Phoenicians made candles, 10–389
How gas came to be used for lighting, 10–390
The limelight and the Welsbach mantle, 10–390
How we found the electric light, 10–390-92
The secret of the firefly, 10–393

Things to Think About

What makes a candle burn?
Why does a lamp shed a better light than an open flame?
What problems did Edison have to solve in order to give us good electric lights?
How does the fluorescent lamp give us light?

Related Material

How much energy does an electric lamp give out in the form of heat? 1–351
What kinds of light are used in lighthouses nowadays? 10–226, 228
Why are some electric bulbs filled with nitrogen? 1–527
How is electric current generated? 1–113, 503-11, 515
How is the electric light used in the "movies"? 10–392, 503-6
How is the neon glow lamp used in television? 10–125
What part does the photo-electric cell play in sound pictures? 10–504
How does the photo-electric cell make television possible? 10–124-25

Practical Applications

How has the electric light transformed the world for us? 10–392-93
How are electric lights colored? 10–392

Leisure-time Activities

PROJECT NO. 1: Make a candle, 10–389
PROJECT NO. 2: Make a firefly lantern, 10–388

Summary Statement

Fires and torches gave the cave man light at night. Other and better ways of making light have been found until to-day we can push a button and light up a whole city.

Photo by Southwest Museum

Gathered around the blaze in front of the cave, our early forefathers tried to fight off the fears that always came with nightfall. Who knew what dangers lurked behind the shadows? And if the fires of a volcano lighted up the clouds with a ruddy glare, that strange, weird light was only the more terrifying.

HOW WE TURN NIGHT *into* DAY

All the Ways of Making Light from the Cave Man's Torch to Our Own Electric Sunbursts

HAVE you ever been out in the woods on a really black night—when there was no moon and when even the stars were hidden under thick clouds? If so, you know just what it is to be blind and not to see a tree right in front of you or your own hand before your face.

Now there was a time when all our forefathers were just as blind as that on a black night. They had no way to make any sort of light, and when the moon and stars failed, they could only do their best to sleep through until sunrise. But it was not very cozy for them, since they might wake up any moment to find a wild beast at their throats. No wonder some of us are still afraid of the dark!

To-day we can push a button and light up a whole city. We can even play tennis or baseball at night. And this is the story of all the ways we have found to make light down through the ages. We wanted light so that we need never feel afraid again, and so that we might work or play at night as well as in the daytime.

The Very First Light

Very long ago we found out how to make a fire, as has been told in another story. As soon as we had fire we could have a light at night; and after that we could sit by the fire at the mouth of our cave and watch the green eyes of some beast who did not quite dare to spring upon us for fear of the blaze.

Of course the fire threw a little light into the cave. But pretty soon we found that we could carry a blazing stick back into the cave and see still better there. To this very day, in the caves of France and Spain where men used to sleep twenty or thirty thousand years ago, we can see holes in the wall where they used to stick the torches; and we can look at the ashes from the ancient torches and the soot that covered the walls of the cavern.

Soon we found a thing that gave a better light than a blazing stick. We were cooking something, and the fat began to burn; and in due time we knew that certain kinds of grease will burn longer and more steadily than a stick of wood. We found out that the best way was not to light the grease, which would just spit and sputter, but to put some sort of wick in it and light the wick. So we poured the grease into the skull of a boar or a deer, and stuck in a wick. In those same caves have been found skulls that were used in this way. They were the first lamps ever known.

Now the strange thing is that they were really the only kind of lamp we had until a century and a half ago!

Of course they were greatly improved. We did not go on using skulls forever, but made lamps out of stone or metal or various kinds of pottery. We made them larger and often more beautiful - so beautiful that some of the lamps from the time of Greece and Rome and from ancient China are treasures to own in our day. But straight down through the days of Greece and Rome, and even up to the time of the American Revolution, we had no lamp that was really different in kind from the lamp of the cave man. And it was a pretty poor one It smoked and flickered, and it gave very little light but plenty of odor.

What a nuisance they were, those little old lamps and lanterns! The Roman lamp at the top burned oil by means of a wick stuck into the smaller hole, at the left. There was nothing to keep a draft from blowing out the flame, and of course there was no way of escaping the odor. And what an unpleasant burn one could get from the hot oil!

There is no way of getting burned from the strange-looking gourd-like affair at the left, for its light all comes from fireflies shut up inside it. These romantic lanterns are used in little native huts in the West Indies.

Photos by Metropolitan Museum of Art and National Museum

When Shakespeare and his friends had to be out in London after dark, they carried a lantern like the one just above. It was a little box of metal with a candle inside. Sometimes it had thin slices of horn set into it to shed the light, and so it was often called a "lanthorn"; but often it was just punched full of holes. And often the wind blew it out! At the right is a plain kerosene lamp, such as always sat on the big table around which our grandparents and our great uncles and aunts gathered to do their sums. It was a great nuisance to clean, and was the cause of many a fire, but the flame on its wick burned clearly and steadily and gave a pleasant light.

The first thing that we should now call a lamp was made about 1782 by a Swiss chemist named Aime' Argand (ĕ'mā' är'gôN'). It provided a good draught for the fire, but put a glass chimney around the flame and thus started a new age in the history of lighting. The flickering and smoking stopped, and at once we had a soft and restful light which in those days seemed very brilliant. Since then we have gone on improving our lamps until we now have them in a great many shapes, sizes, and kinds. The best of them give an excellent light for reading, and there still are more lamps used in the world than any other kind of light But they need cleaning and refilling; they make a good deal of heat, and use up a good deal of the oxygen in the air--about four times as much as a man breathing;

they flutter or go out in a breeze, and they are always a little dangerous.

What Makes a Candle Burn

We had begun with mere grease. In time we went on to various oils, all obtained from some plant or animal. The main kinds were the rape oil that came from a plant like a turnip and, much later, the sperm oil that came from whales. Down to the time of our great-grandfathers, these were the best things we had.

But what about kerosene? Well, strange as it may sound, we did not know how to use kerosene till about 1853. And then it made another revolution in lamps though for some time, as we shall see, we had already been using gas.

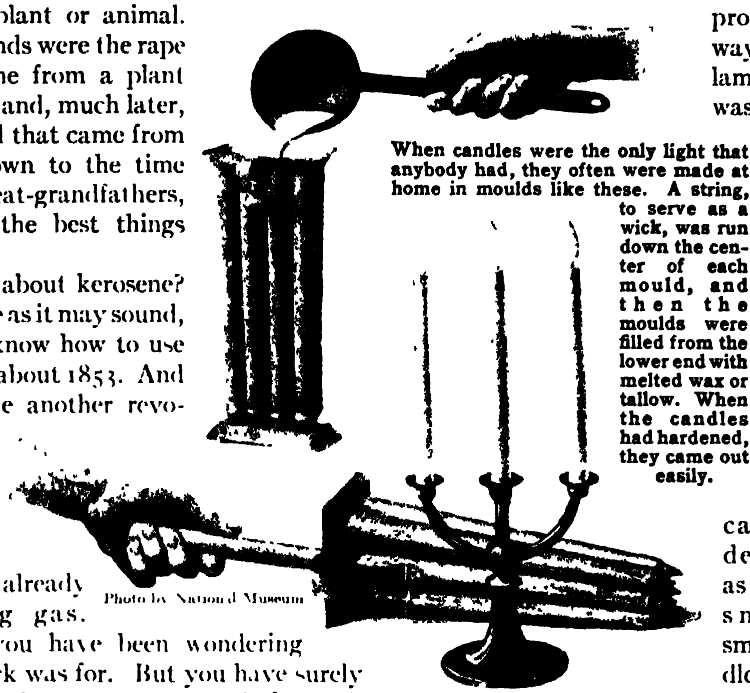


Photo by National Museum

When candles were the only light that anybody had, they often were made at home in moulds like these. A string, to serve as a wick, was run down the center of each mould, and then the moulds were filled from the lower end with melted wax or tallow. When the candles had hardened, they came out easily.

Perhaps you have been wondering what the wick was for. But you have surely noticed that when you put one end of a small tube in a pail of water, the water will run up a little way inside the tube. If the tube is very fine, like a hair, the water will rise all the way to the top, but it will not spill over. We have no notion why it rises; it just rises. When we do not know about a thing, we often give it a big name; and this thing we call capillary (kăp'ĭ-lâ-rĭ) attraction, from the Latin word which means "hair." Now a wick is full of little spaces between the fibers through which the oil rises to the top; and in the lamp it keeps coming up just as fast as it is burned away. In a candle the wick does the same thing; only here there is a neat little arrangement by which the heat keeps melting the top of the candle so that it may keep flowing up the wick.

And now we have to go back again in ancient times to the Phoenicians, about whom we hear so often in these stories. It seems to have been these people who first ran a thread of yarn through some tallow, or animal grease, and so made the first candle. And down through the ages their candle has come side by side with the lamp, as the other successor of the cave man's torch. Of course it was improved in many ways, just as the lamp was. It was often made of beeswax, or much later of spermaceti (spûr'mȧ-sĕ'tĭ) from a whale's head; and sometimes it was sweetly scented, as in bayberry candles. Indeed, as long as lamps were smoky and smelly, the candle was often preferred. And it is still used in our own day, though mainly as an ornament. At many a fine dinner there are candles on the table.

Our great-grandmothers used to make many a candle. They would lower a strand of cotton into a tank of wax and draw it out to let it dry; then dip it and dry it again and again until it had gathered enough of the wax to be a good round candle. Nowadays a candle is usually just poured into a mould around a wick and allowed to harden. It is often a mixture of many materials, but principally of stearin and of paraffin wax.

But how slow we were in finding out how to make a good light! Down to the time of George Washington, which was only yesterday as history goes, we had nothing but smelly lamps and ghostly candles. In all the palaces of Louis XIV there was nothing better.

So imagine the surprise of some old cave man, or of Louis XIV either, if he had

heard that we were going to get light out of one of the blackest things that we could find—out of lumps of coal. For some time we had known that we could get gas out of coal and burn it, but it was only about 1792 that we began to learn how to make all the light we needed in this way. By 1802 a Scotchman named William Murdock had lighted a large factory near Birmingham with gas, and two years later a German named Wintzler lighted a theater in London with it. How much did one see in a theater before there was a gaslight?

Or how much did he see in the street at night? For there was no way at all to light a street when we had only lamps and candles—they would blow out in the wind. That is why a man in Shakespeare's London who ventured out at night carried a lantern and a drawn sword. And the lantern was only a tin box with a candle in it. But with gas we could even light a street. And the same Wintzler had soon lighted the famous London street known as Pall Mall.

In the square is a picture of the old-fashioned gas jet, in which the gas burned in a fan-shaped flame. Below it is the Welsbach gas mantle, which gives out a much brighter light than the little contrivance above.

His little yellow gas jets would look pretty weak to-day, but a century ago they were a new wonder. In the pitch dark even the flare of a match looks bright. And people were soon talking about the brilliant "lights of London town." When they wanted to celebrate some great event they put up scores of extra gas jets and lighted them all at once to make what they called an Illumination.

What Is the Limelight?

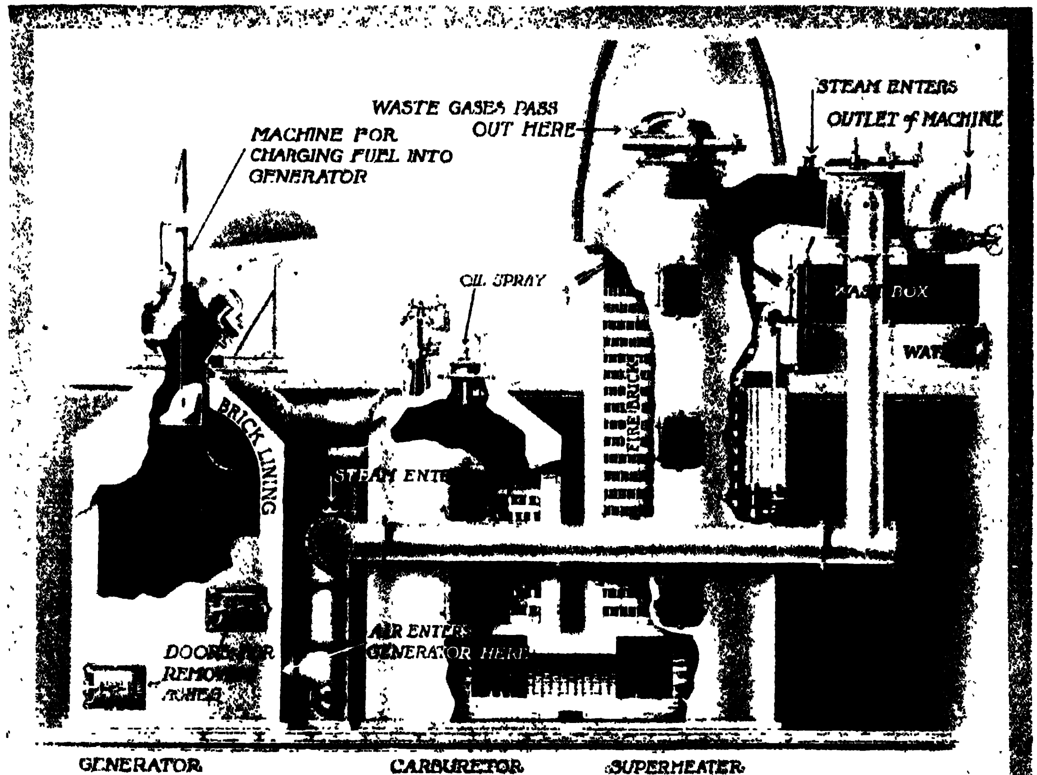
Then of course the gas jet was vastly improved. At the very first it had just been an ordinary hole at the end of the pipe, which let out ten times too much gas but gave ten times too little light. But soon there were various kinds of jets with little slits that let out a bright, flat flame in the shape of a fan. The old-fashioned gas jet of our own day is like that. But it is getting to be rare.

For a good while ago we found out the curious fact that certain things which will not burn over the hottest flame will yet turn so bright as to give out far more light than will the flame itself. They give out "incandescent" (ĭn'kăn-dĕs'ĕnt) light—or light that comes from something glowing but not burning. Lime is one of these things. If we heat a cylinder of lime hot enough, it will throw off a dazzling light—and that is why we still talk of being "in the limelight," for in its day this was the brightest light of all.

Now in 1885 a German named Welsbach (vĕls'bäK) put a little cone, or "mantle," made mainly out of a metal called thorium, over a gas burner. When the mantle got white-hot it gave off a light far brighter than the gas itself could give. And the "Welsbach mantle" is what we still use if we light a room with gas. But we now use gas for cooking and for other purposes more than for light. It had its day of glory, and then bowed to a superior invention. Yet some of us with gray hair can still remember when we first came to a great city hotel and found a gas jet in our room! And there may have been a sign reading "Don't blow out the gas." For once in a while a backwoodsman would blow it out, like the lamp at home, and then die in his sleep. One or two men are even said to have tried to blow out the electricity.

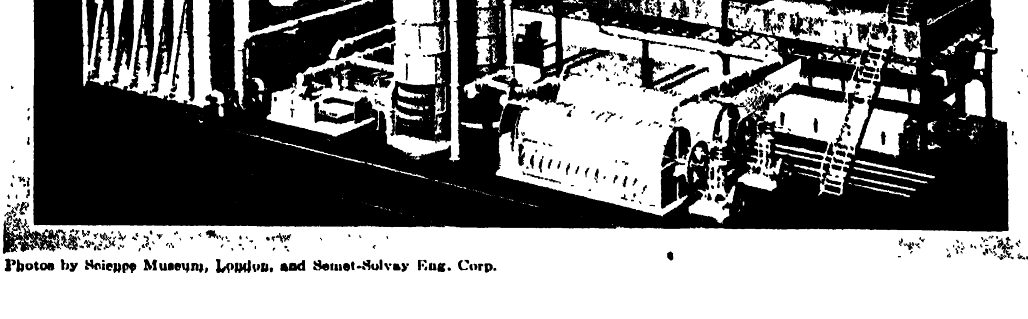
For finally we found the electric light. There is nothing burning in it, only something shining. You do not have to touch a match to it, but just press a button. The last child of the cave man's torch is only a hot wire in an empty bulb!

For some time we had known that when an electric current runs through a fine wire it will make the wire red-hot and give off light. As far back as 1820 a Frenchman managed to make an electric light that lasted for a little while; and he was followed by a



The plant above makes water gas by driving steam through coal or coke in the generator, where a blast of air has made the fuel very hot. The steam picks up gases from the fuel and passes to the carburetor, where a gas given off by very hot oil is added to it. This gives the gas made from the coal or coke a much higher heating value. In the superheater the two gases are well mixed, and water in the washbox takes tar from the mixture. The gas is then dried and purified, and is ready to burn.

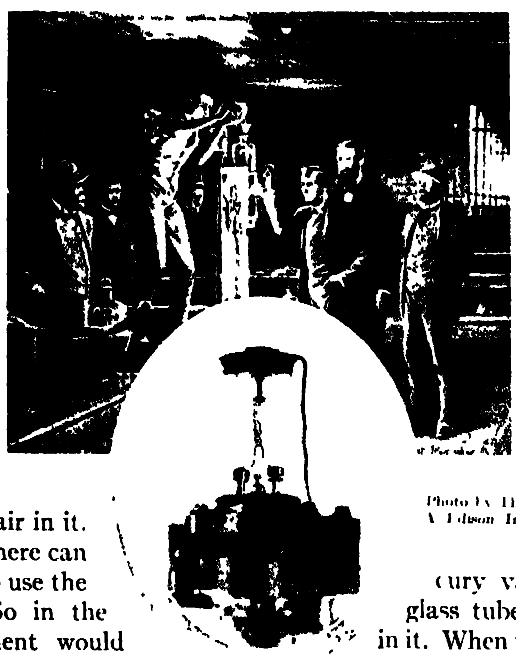
Below is a model of a coal-gas plant. Soft coal is heated very hot in air-tight ovens, and so made to give off a gas that will burn freely. This gas passes through mains to a cooler, where it is chilled by passing through pipes surrounded by water. Then it is treated in various ways to remove tar, ammonia, light oils, and other impurities, all of which have great commercial value. The pure gas is then stored in a great tank, ready to be pumped to consumers. Water gas has replaced coal gas in most of our cities.



Photos by Science Museum, London, and Semet-Solvay Eng. Corp.

number of other men, until finally a large hall was lighted in this way in 1840. But none of the early electric lights were very good.

There were two main problems: to find the kind of wire that would make a bright light, and to keep the wire itself from burning up as soon as it got white-hot. In 1878, following many other workers, Edison found the best answer that had yet been given to both problems. He tried wires, or filament, of many substances --paper, thread, and bamboo among them—all of them charred to turn them into carbon. And to keep his filament from burning up, he put it into a glass bulb that had no air in it. Where there is no air, there can be no fire, for fire has to use the oxygen in the air. So in the empty bulb the filament would shine for a long time without burning away.



In the large picture is the scene in Thomas Edison's laboratory at Menlo Park, New Jersey, on the night in 1879 when the first successful incandescent electric lamp was prepared for its life test. Edison, the third from the left, is preparing the filament. At the bottom is a picture of Edison's first successful incandescent lamp. The filament was made of platinum and iridium, and there was a device to turn off the current whenever the metal got too hot. The lamp burned for forty hours.

In the fairly short time during which the electric light has gone all over the world, it has seen a vast improvement. The old filament was just a single loop that gave a dull yellow glow—not so bright as the Welsbach mantle. But by 1907 we had multiple filaments made of the metal called tungsten, and these are now so bright as to give some eight times more light than we could get at first. Our modern electric lights are of all sorts and sizes, up to the enormous spotlights of thirty thousand watts used in the moving-picture studios.

A Light for Every Need

But we have told of only one kind of electric light, and there are still others. One of these is the arc light. It came as early as 1845, and was in use to light the streets of Baltimore by 1870. For a long time it was a favorite form of street light, and people who are now getting gray can remember how the arc lights used to buzz and sputter on the corners in their childhood.

The arc light has two sticks of carbon placed end to end but not quite touching. When the electric current leaps from one stick to the other it makes an intense heat; and a blue arc of vaporized carbon forms between them and throws off a brilliant light. Such a light is still used for certain purposes, but it no longer lights our streets.

Since 1901 we have had the mercury vapor lamp. This is a glass tube with a little mercury in it. When the electric current runs through it, the mercury turns to gas and glows with a beautiful and weird blue light. Still prettier is the neon light, which we have had since 1911. It works in about the same way; only under the current the neon gas in the bulb turns to a bright orange color. We often see this in a long glass tube which has been turned and twisted to form words or pictures. It is widely used in advertisements and in other signs. We can add still other gases and turn the light in it to blue or green or various other colors.

There is also another kind of gaslight that we have not mentioned. It is made with acetylene (ȧ-sĕt′ĭ-lēn) gas, which is formed from calcium (kăl′sĭ-ŭm) carbide and water. It was used for the headlights of motor cars before the electric light was perfected for

that purpose; and it is still employed in some country houses that are too far away to get gas from a town and have to make their own. It burns with a fine white light.

But there is still one kind of light we cannot make. Some of the bacteria can make it, and so can the fireflies. It is "cold light." For we can make light only by burning something or heating something—only by making more or less heat at the same time. But there is so little heat in the light of the fireflies and certain far tinier creatures that we call their beams cold. We have learned how to imprison the lightning in a little tube of glass, but we have not yet found out all the secret of the firefly. There are men who are wondering right now how to do it. Possibly they will find out.

As recently as 1938 they came much nearer to solving the problem. At that time a new kind of electric lighting known as the fluorescent (flōō'o-rĕs'ĕnt) light was evolved. It is shed by a glass tube filled with mercury vapor under low pressure. Inside, the walls of the tube are coated with one of a number of different chemicals. When an electric current is passed through the mercury vapor, invisible ultraviolet rays are produced, and these rays, striking the chemical-coated walls of the tube, are radiated again as rays of visible light. The light is white or one of a variety of colors, depending on the chemical that has been used to coat the walls of the tube. Practically no heat is generated in the process.

This light that is emitted by various substances when they are exposed to the action of certain kinds of rays is known as fluorescence. We may see it at work when we look at our hands under the X rays, for X rays will make certain substances fluoresce --that is, emit fluorescent light.

Fluorescent tubes are a good deal more efficient than the old-fashioned bulbs that shed their light from a heated filament inside the bulb. Fluorescent tubes give three times the light on the same amount of electricity. They can do this because almost no energy is lost in heat. Furthermore, fluorescent light is said to be more like natural daylight than any other kind of artificial light and for that reason easier on the eyes. The tubes may be straight or bent to form a circle.

Fluorescent light was widely used for the first time at the New York World's Fair in 1938. During World War II it was common in industry, and helped to speed up war production. To-day it is appearing more and more often in our homes, where its soft glow is said to help us avoid the eye strain that modern life inflicts on us.

Many other interesting kinds of lamp bulbs have been invented of late. Scientists and engineers, realizing the tremendous value of the rays of the sun, are learning to bring us some of the same life-giving energy in rays emitted by electric bulbs or tubes. The deeply penetrating heat of the diathermy (dī'ȧ-thûr'mĭ) machine relieves the aches and pains of arthritis and similar diseases. Another kind of bulb will give us the heat necessary to dry paint quickly on a long production line of new cars or planes. There are bulbs which help create vitamin D and give you a becoming sun tan at the same time. And another newly developed electric lamp is capable of destroying harmful air-borne bacteria. It has been put to work in many of our public buildings, schoolrooms, and hospitals. All these light-giving devices are a little like the sun come down to earth.

We still measure any kind of light in the terms of the old candle. A candle power is the amount of light given off by a spermaceti candle of a certain size that is burning at the rate of a hundred and twenty grains of wax an hour. A lumen (lū'mĕn) is the amount of light that such a candle would throw on a square foot of paper one foot away.

And now suppose we think a moment about how the electric light has transformed the world for us. The shades of night are falling on the city. Somewhere a man is pressing a row of buttons, and mile after mile of street begins to glow with thousands upon thousands of electric brilliants. In story upon story of the towering steel buildings the lights are flashing on, until the whole scene is a fairyland that we could never dream of till we see it. Light is turning the darkness into day. Just suppose the old cave man could see it all!

Reading Unit No. 7

THE MACHINE THAT MADE THE WORLD OVER

Note: For basic information not found on this page, consult the general Index, Vol. 15.

For statistical and current facts, consult the Richards Year Book Index.

Interesting Facts Explained

What steam can do, 10–395-96
The secret of the steam engine, 10–396
A sort of steam engine was made by Hero of Alexandria, 10–396
The steam engine that worked backward, 10–396
How the Newcomen engines pumped water out of English coal mines, 10–398
James Watt makes the first successful steam engine, 10 400-1
How a governor on a steam engine works, 10-401
The modern turbine engine, 10–401

Things to Think About

How did the Newcomen engine work?
What were the chief defects of the Newcomen engine?
What parts of the steam engine did Watt perfect?
How does a steam turbine differ from a steam engine?

Related Material

What ship deserves the credit of being the first steamship to navigate the Atlantic? 10–222
How is steam formed? 1–404
Is steam a suitable refrigerant? 1-408-9
How is electric power generated? 1-506, 507-8
What were the earliest steam vehicles? 10–175-83, 277, 280
How does steam drive the railway engine? 10–175-78, 277
What fuels are most commonly used? 1–384

Leisure-time Activities

PROJECT NO. 1: Use a jet of steam from a tea kettle spout to spin a spinwheel.

PROJECT NO. 2: Make a model of a Watt steam engine governor, 10–401

Summary Statement

Steam is the gas that water turns into when we boil it, and its power comes from the fact that it needs about sixteen hundred times as much room as the water it came from. The invention of the steam engine, which we owe to James Watt, was the main event that started our modern Machine Age.

Photo by Rischgitz

Of course James Watt's parents do not yet realize that their son is a genius, though it is clear that they think he is an uncommonly nice little lad. They are waiting for the lid to fly off the kettle, for James is stopping the spout They will laugh at James's surprise, and then the incident for them will be over But for James it will be the beginning of a train of thought that will change the lives of all mankind.

The MACHINE THAT MADE *the* WORLD OVER

Our Modern World Got Its Muscle from the Steam Engine Built by James Watt

JUST suppose one of our ancestors two or three hundred years ago had had to lift a ton of stone a foot high, how would he have done it? He would have had to get a dozen or so men with long levers to pry it up by might and main.

And then suppose we had come along with a tiny cup of water and said, "Let the water lift your rock for you!" We can imagine how he would have laughed at our nonsense. Lift a rock with a few spoonfuls of water?

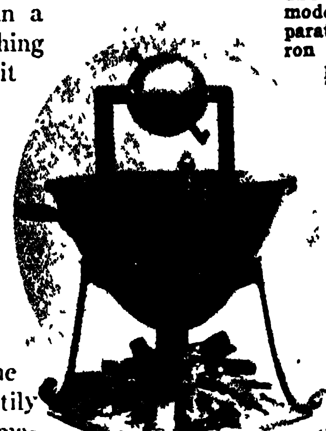
Yet a cubic inch of water, if we put it to work right, will lift a ton of rock twelve inches To make it do so we must first change it into steam, and a cubic inch of water will make about a cubic foot of steam And then we must have an engine that will put the tremendous power of the steam to work.

Now steam is simply the gas that water turns into when we boil it And its power comes from the fact that the steam expands about sixteen hundred times, or needs about sixteen hundred times as much room as the

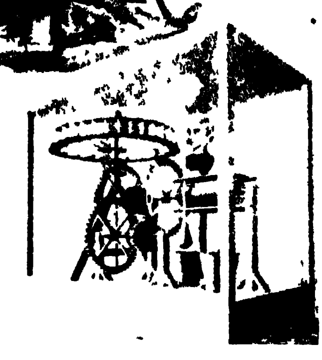
water it came from. If we boil the water in a pan the steam will merely flow off into the air, and will seem to have no power at all. But if we boil it in a bottle or a sealed can, we shall want to get out of the way in time, for there will be an explosion.

How to Harness Steam

But if we are going to use the steam, we must not let it float away in the air, and we must not have it exploding. We must keep it compressed in a strong steel box, pushing mightily to get out—it will push in all directions with a force of two hundred pounds or more to every square inch. And there must be one place where it can get out, but only by pushing something ahead of it. Then the thing it pushes so mightily is connected with the machine we want to run—in a locomotive, for instance, with the wheels on the track. The force of the escaping steam is what makes the wheels go round. And that is all the secret of the steam engine.



The picture in the oval shows a model of Hero's little steam apparatus. Water in the big cauldron was brought to the boiling point by a fire underneath. The only way of escape for the steam was through the two pipes leading into the hollow globe above, which was provided with two little spouts. The force of the steam rushing out of the spouts started the globe spinning. This device was never put to work.



In the square is a model of an engine made in 1629 by an Italian named Giovanni Branca. The big wheel at the top was turned by a jet of steam which, rushing out of a pipe, hit a great many little blades set on end along the edge of the wheel. This made the big wheel turn; and the big wheel turned other wheels that might have accomplished some sort of work if the device had been big enough and if a strong enough jet of steam had been applied. The modern steam turbine operates on the principle of Branca's engine.

Photos by Science Museum London

But it took us a long time to find out how to use the secret. We have had steam engines only for about a hundred and fifty years. And in that short time they have just about made the world over for us.

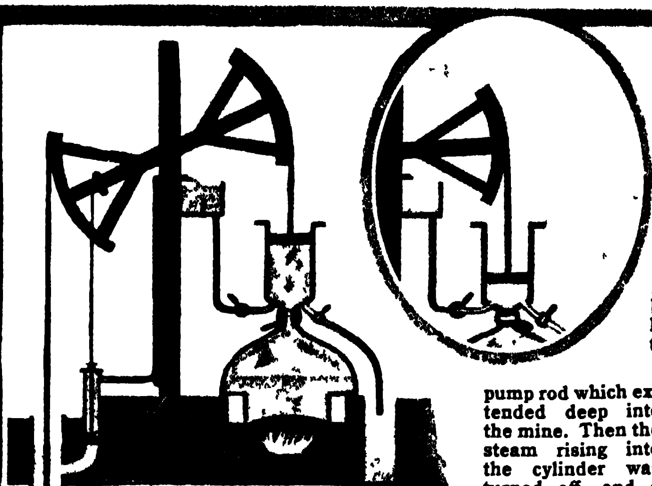
Of course we knew something about the great power of steam long before we found out how to put it to work. A good many men were wondering about it. About 2,000 years ago a certain Greek named Hero of Alexandria is said to have made a sort of steam engine. It was only a kind of whirligig, and just a toy; of course it was never put to work.

For many a century there was nothing better. There are certain stories about rude steam engines three or four hundred years ago, but we are none too sure how true they are. A certain Spaniard is said to have made a steamboat about 1543 and to have sailed it across the Bay of Barcelona. And about 1629 an Italian blew steam out of a pipe upon a wheel and made the wheel turn like a sort of windmill. But the mill was not strong enough to do any real work.

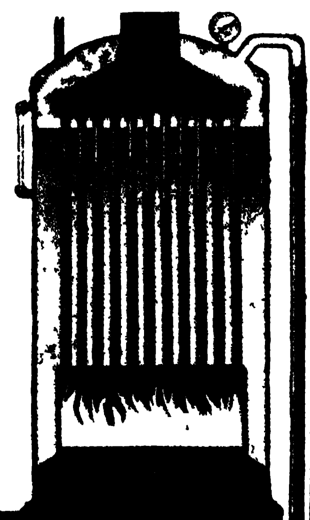
By 1698 steam was finally set to work by an Englishman named Thomas Savery, though in a fashion very different from the way we use it. When you drink lemonade through a straw, what you do is first to suck out the air in the straw, and leave a vacuum, or empty space, in it. Then the lemonade flows up into the empty straw, for "Nature abhors a vacuum." The weight of the air pressing down on the surface of the lemonade in the glass pushes the liquid up into the vacuum. Now that was just the way that Savery's steam engine worked.

A Steam Engine That Worked Backward

He wanted to draw water up into a tank without pumping it. So he first filled the big copper tank with steam. Then the steam cooled and turned back into water, leaving nearly all the tank a vacuum. And up into this vacuum, through a pipe, came the water from below, just as did the lemonade in the straw. For a long time this



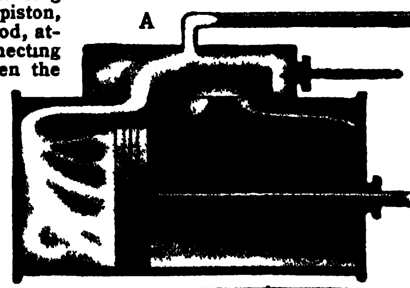
Left: Newcomen's engine, for pumping water out of mines. Water in the boiler, heated by the fire underneath it, gave off steam which rose into the cylinder above and pushed up a sliding disk called the piston. Attached to the top of the disk was a piston rod which was connected with a rocking beam. As the piston rod rose, the right-hand end of the beam rose with it, and the left-hand end of the beam sank, at the same time pushing down a pump rod which extended deep into the mine. Then the steam rising into the cylinder was turned off, and a stream of cold water was turned on. It flowed into the cylinder from a little tank fastened to the upright wooden post at the left. The cold water condensed the steam in the cylinder, and so a vacuum was formed. Since there now was nothing to hold up the piston, it sank to the bottom of the cylinder—as shown in the oval—pulling the right-hand beam end down with it and raising the left-hand beam end and the pump rod down in the mine. The cool water in the cylinder ran off through the pipe at the right. Then the whole process began again. Water was pumped into the tank by a second pump rod on the left-hand beam end.



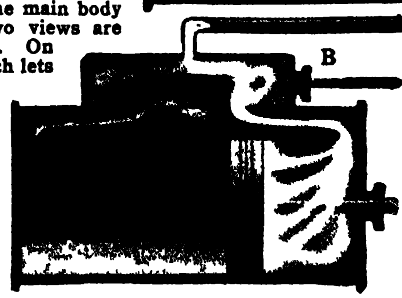
HOW A MODERN STEAM ENGINE WORKS

Right: Boiler and cylinder in a modern double-acting steam engine. At the top you may see how tubes running through a boiler full of water carry heat from the fire below and so keep the water at the boiling point. The steam gathers in the boiler under great pressure. Then, when a stopcock is opened in the pipe at the right, the steam rushes through the pipe to the cylinder, which it enters at A, as shown in the center picture. The pressure of the expanding steam forces a sliding metal disk, called the piston, along the cylinder to the right; and the piston rod, attached to the piston, pushes a metal shaft connecting with a wheel. So the wheel is turned. When the piston reaches the right of the cylinder, as shown in the lowest picture, a neat affair called a slide valve is at the same time automatically slipped to the left across the left-hand entrance to the cylinder, and the right-hand entrance is opened for the steam to rush into the right-hand end of the cylinder (B) and push the piston to the left. The returning piston drives the used steam out of the cylinder through the opening in the center of the slide valve. In both pictures the slide valve is shown just above the main body of the cylinder, for of course the two views are both pictures of the same cylinder. On top of the boiler is a safety valve which lets steam escape if the pressure inside the boiler becomes too great for safety. We measure an engine's power in "horse power," because early buyers of an engine wanted to know how many horses it would save them. A one-horse-power engine must supply the power to raise 33,000 pounds one foot per minute.

A



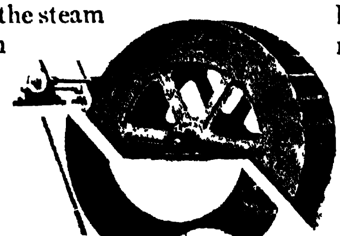
B

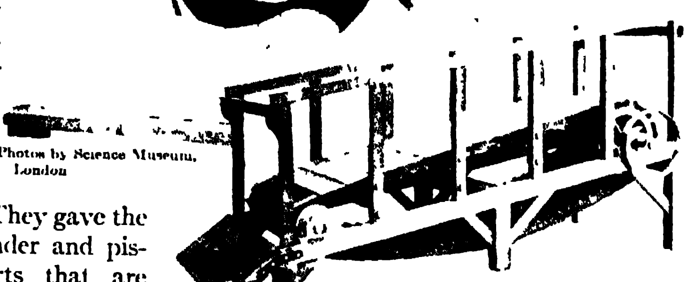


sort of engine was used to draw up the water out of mines.

We may say that it was a steam engine that worked backward. Instead of making water expand into steam and push something out, it made the steam condense into water and draw something in. And nearly a hundred years were still to pass before the great James Watt came and turned the process around so that the steam worked with a push instead of a pull.

In the meantime Savery's engine had been improved by a Frenchman named Papin (pà′-păN′) and by an Englishman named Newcomen. They gave the engine a cylinder and piston, two parts that are found in every steam engine today. The steam that enters the cylinder pushes the piston back and forth and so operates the machinery.





Photos by Science Museum, London

Here are two ways by which men turned their wheels before they put steam at work. The upper picture shows an undershot water wheel invented by a Frenchman named Poncelet. The wheel was hung inside a narrow wheel pit. The water, which was on a level with the top of the pit, at the left, was held back by a movable sluice. When the sluice was raised, a stream of water, flowing down an inclined channel at the bottom of the wheel pit, hit the curved blades of the wheel and pushed them forward to the right. This sent the wheel around. The outline of the wheel is here shown painted on the outside of the wheel pit, together with the position of the water as it pushes against the bottom of the wheel. This was the kind of wheel best suited to a shallow stream.

A horse furnished the power for the lower device. The unlucky beast was driven up the inclined plane to the movable platform. All day long he walked and walked on the platform, which his steady tread pushed out behind him. So the plane passed under the horse and around, under and around, and turned the wheel shown at the right of the picture.

In Newcomen's engine the steam did push the piston out; and then cold water was squirted into the cylinder to condense it and to leave a vacuum which would pull the piston back. Then more steam would be let in to push it out again, and so the process would continue at the rate of some sixteen strokes a minute. The modern steam engine commonly makes about ten times as many strokes.

The Invention of a Lazy Boy

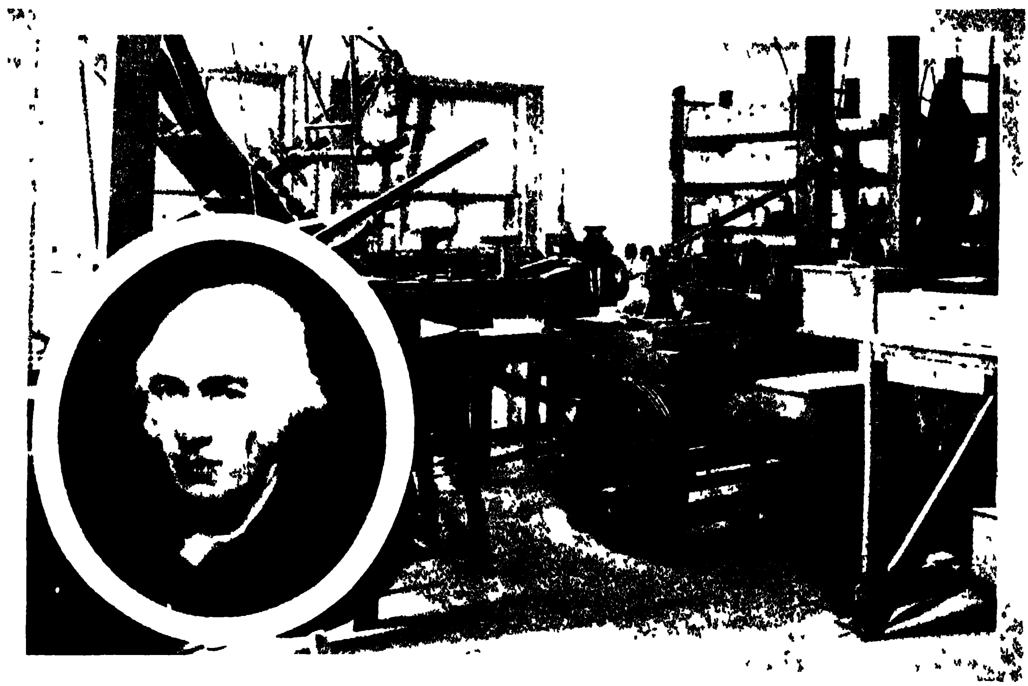
The first Newcomen engines could not run by themselves. Someone had to stand by and open valves to let the steam and water in and out of the cylinder. The story goes that a clever boy named Humphrey Potter thought of a better way. He was hired to open and shut the valves, and he grew tired of the tedious work. So he just tied some strings to the handles and bars and beams of the engine, and so made it open and shut its own valves at the right moment. In this way the boy is said to have invented the slide valve, which is now an important part of every steam engine.

The Newcomen engine slowly pumped the water out of many an English coal mine all day long for many a year. But it often gave trouble. It would spring a leak or get into a jam or find some other way of going wrong. And the worst thing was that it ate up so much coal. Never did an engine need so much coal to get up steam enough to do its work. For heating the cylinder with steam for every stroke and then cooling it at once again was by no means a good idea.

Yet it did manage to pump water, and for a good while no one thought of any better thing. Indeed, there was not much machinery to run in those days, for nearly everything was done by hand. The Newcomen engines were never used for anything but pumping water. And so there were not very many of them. Even blacksmiths and machinists usually knew nothing about them. We may be fairly sure that James Watt, who was soon to give us a far better machine, never saw one of the Newcomen engines when he was a boy.

Yet there is a story about the boy Watt that we always love to tell, even if we know it is not quite true. It is the tale about his listening to the kettle singing, watching the vapor pouring out of the spout, and wondering what would happen if the spout were stopped up. So he just tried it to see, and

His father did a business of supplying ships with everything they needed. So the storehouse was full of rope and canvas, with a strong smell of oakum. But best of all, there was a carpenter shop where all sorts of things were turned and shaped for use on shipboard.



Photos by Science Museum London

This is a picture of James Watt's workshop, as it has been reconstructed in the Science Museum, in London. It was here that his steam engine was born. In the oval is a picture of the great inventor.

found that the steam pushed off the lid of the kettle at once. And that, according to the story, is the way James Watt got the idea of the power of steam and started thinking about his engine.

The Boyhood of James Watt

The fact is that when Watt was a boy in Scotland, where he was born in 1736, he had other things than kettles and steam engines on his mind. He had his lessons and his games, and his rambles over the Scottish hills. He was also a great reader, and never so happy as when he had a good book. But he was a sickly boy, and sometimes he had to stay away from school for weeks at a time. Then he often found his father's shop the best sort of place to play in.

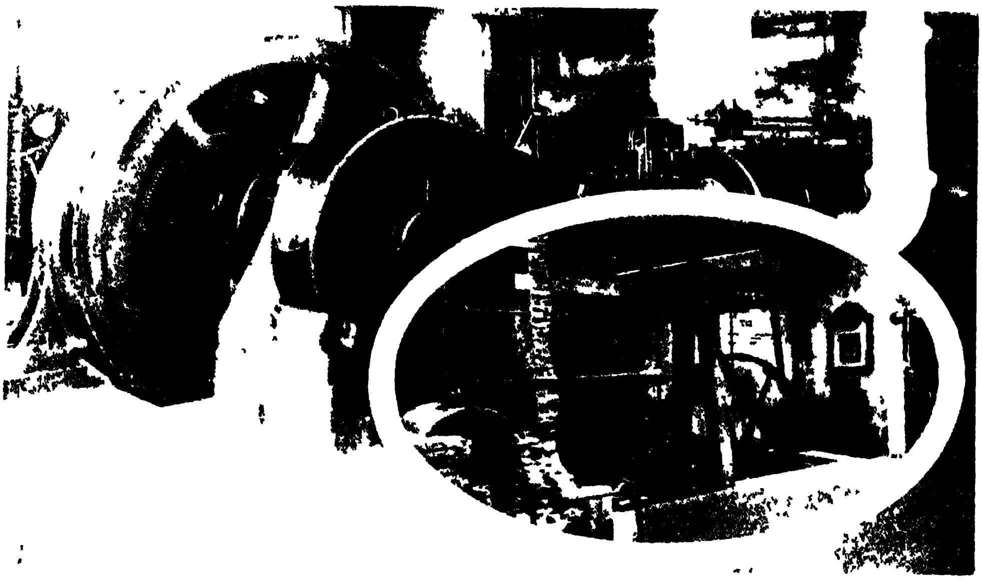
In the shop the boy learned how to make many things out of wood and metal. He liked to build models of machines, and soon grew to be an expert with every tool in the shop. By the time he was fifteen the good folk in his native town of Greenock had begun to think that Jamie was a bit of a genius.

He meant to go off to college—like a good Scotsman—but just when he should have started, his father lost most of his money, and James had to go to work for a living. The natural thing for him was to become an instrument maker. That was easy work for him, and he would like it.

Watt Visits London

So off he went to London, with a friend on horseback. Once in the city, he had

little trouble finding work as an apprentice to a maker of instruments. In those days anyone who wanted to be a skilled worker had to serve for many years as an apprentice, and to work very hard for very little pay. At the end of his first year young Jamie found that the long hours and the poor food



Photos by the Deutsches Museum Munich

The powerful giant in the large picture is a modern steam engine. It and thousands of its fellows help to drive our modern world. In the oval is its little old ancestor, James Watt's first engine, of 1788.

were telling on his health. He had to give up the work and go back home.

The Birthday of the Machine Age

As soon as he was well again he went to Glasgow and began making instruments for the University there. That was in 1756, and for the eight years following he was busy making mathematical instruments and working at engineering problems that were set for him to solve.

At last came the great day when he started on the work that was going to make the world over. There was a Newcomen engine in the museum at the University, and Watt was called upon to make some repairs on it.

He had no trouble in doing that, but the more he studied the engine, the less he liked the crude way it had of working. It wasted too much heat and got up too little power; and it went too slowly. Couldn't he manage to make something better?

He wanted an engine that would keep hot all the time instead of cooling off at every stroke. He wanted one that would not have to wait for a vacuum to form. If he could build one, it would work faster and harder than the old Newcomen affair.

For three years Watt pondered and experimented without making any headway. But he knew there was an answer to his problem, and he was still sure he could find it. Then as he was walking over the common in Glasgow one day, he found the right idea coming into his head all at once. So he hurried home and started to build a model.

The First Successful Steam Engine

But even with the right idea, a great invention is not finished in a day. For many a year still Watt had to struggle against discouragement, failure, and occasional despair. He made a little model that worked well enough, then he built a big engine on the same model, with money he had borrowed,

and the engine did not work at all. It had been so badly made that it was full of leaks and would not run.

Then Matthew Boulton of Birmingham came and offered to join Watt as a partner. Together they found better ironworkers and mechanics, and built a new engine that was a great success.

In its general way of working their engine was very much like the engine of to-day. In the pictures you may see the parts that the genius of Watt invented. Notice especially the slide valve and the governor. It was he who thought out and perfected both of these.

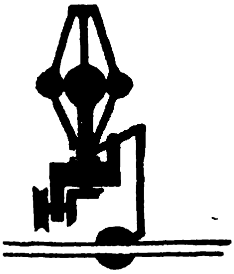
The condenser was one of his great triumphs. With it he could pull out the steam when it had been used, without cooling or stopping the engine. Then the engine could run faster and exert more power. And the governor is a neat little device to keep the engine from running too fast or too slow. It has two little iron spheres that just hang down when the engine is at rest, but fly out like balls on a string when it is running. The faster the engine goes, the faster the governor whirls and the higher the balls fly. But they are so attached to the machine that when they get too high they will operate so as to turn off some of the steam and in that way slow the engine up a bit; and if they fall too low they will likewise speed it up a little by turning on more steam. So they keep it always going at a steady speed.

James Watt kept on working at his engine, improving and perfecting it, till he was sixty-four years old. Then he retired to enjoy his many hobbies. He thought out a way of copying sculpture. He made a study of the gas that we burn in stoves; and he tried to find out what water is made of. He kept busy right up to the time of his death in 1819. He was one of the greatest inventors of all time; and we often use his name without thinking of it, for we employ the word "watt" as the name for a measure for electricity.

If Watt had lived just a little longer, he would have seen greater wonders done with his engine than even he had ever dreamed. He could have watched it hauling heavy trains across the continents and driving immense ships across the oceans. He could have seen it whirling the wheels in a million factories, and doing nearly all the hard and heavy work of the world. For his steam engine was the main thing that started our Machine Age. And because of it we can have and do thousands of things that the very kings and emperors were missing only a little while ago.

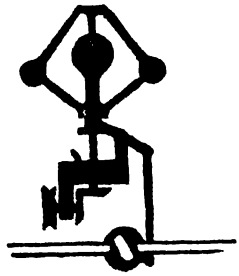
Even Watt's invention, great as it was, was not the last word in the use of steam. Another kind of steam engine was made in 1884 by an English engineer named Parsons. In this engine the steam is made to rush out of a pipe with a tremendous force. Then it strikes upon a wheel with many little blades, and makes the wheel whirl round as fast as two thousand times a minute. There are many of the wheels, and the steam goes from one to another until they are all spinning with tremendous power.

Such is the turbine engine that is now used to drive many big ships over the water and to turn many electric dynamos on land. Of course in our day electric engines have begun to take the place of steam ones in some places. Perhaps they will go on taking its place. But as long as the world lasts it will always remember the miracle that James Watt did with a little familiar steam.



HOW A GOVERNOR WORKS

If you swing a stone tied to a piece of cord you will find that the faster you swing it, the higher the stone will fly. This is the principle that controls the governor on an engine. Those two small metal balls hang on arms that are hinged to the top of an upright spindle, and the spindle is turned by the engine. So when the engine is working fast it turns the spindle very rapidly and whirls the balls through the air at a great rate. This makes them fly outward. Now they, in turn, are attached to a metal collar by their lower arms. This is pulled up when they fly out, thus operating a lever which closes a valve in the steam pipe that supplies the engine. This regulates the speed of the engine.



Reading Unit
No. 8

THE GREATEST FLOWER HAS THE WORST SEEDS

Note: For basic information not found on this page, consult the general Index, Vol. 15.

For statistical and current facts, consult the Richards Year Book Index.

Interesting Facts Explained

Alexander's soldiers bring back brightly colored cotton cloth from India, 10-403

When cotton was a stuff for rich and noble persons only, 10–404

"Long-staple" and "short-staple" cotton, 10-404

Our cotton gins patterned after those used in India, 10 404-5

How cotton was ginned by hand, 10–405

Eli Whitney invents the modern cotton gin, 10-406

How the work of ginning is done rapidly and well, 10 407

Picture Hunt

What did Eli Whitney's first cotton gin look like? 10 404

What happens to King Cotton at the ginnery? 10 407

Related Material

What important facts should we remember when choosing between cotton and woolen garments? 14–550

How is cotton woven into cloth? 9–27-34

What insect is the chief foe of the cotton plant? 9–33, 3–339, 341

What kind of cotton is used in the making of rayon? 9–86

What invention made slavery very profitable in the southern states? 7–217

Of what use are the cotton seeds? 9–33

How is cotton thread spun? 10-339-42

What good reason is there for wearing light-colored cotton clothes in summer? 1 430

Practical Applications

Whose work "saved" King Cotton? 10–406-7

How is cotton cleaned? 10–407

Leisure-time Activities

PROJECT NO. 1: Make a model of a simple cotton gin, 10-404

PROJECT NO. 2: Remove the seeds from a ball of cotton by hand, 10–405

Summary Statement

After the invention of the modern cotton gin, the planting and weaving of cotton became one of the world's great industries, and then cotton cloth was to be had by rich and poor alike.

All through the realms of King Cotton at harvest time the workers come in from the fields laden with great baskets piled high with fluffy white. Now they are "weighing in," for they are paid by the pound. When it has been weighed the cotton will go straight to the cotton gin to be combed free of its little brown seeds.

The GREATEST FLOWER HAS *the* WORST SEEDS

This Will Tell How King Cotton Made It So Hard to Get His Seeds Out Until a Yankee Teacher Made a Machine to Do It

IN THE old days when most of the people in Europe were still barbarians who went around in the skins of animals and in certain coarse woolen stuffs, a few rare travelers from the valley of the Nile might possibly bring some fine fabrics to show them. The Egyptians had long been skillful in the arts of spinning and weaving. A great deal later, when the great Alexander's soldiers and other men crossed over the mountains and the deserts and found their way into India, they would bring back, among other things, many a yard of goods of delicate weave and gorgeous hue. For centuries in Europe these fine fabrics were going to be almost as rare and costly as the gems and spices that came with them out of the mysterious East.

Even more wonderful, the rare travelers in the earliest days would tell of having seen little trees bearing the "wool" that had been woven into these fabrics. In other words, they had come upon the cotton plant. And nothing else that they found in the East was going to be half so important. For in our day the cotton industry is one of the greatest in the life of man.

Nobody knows how long the people over in India had been growing cotton and making cloth out of it. Nor do we know how or

when the Egyptians first found out about it. In the Bible we are told that Aaron, the high priest, wore purple and scarlet raiment, and a girdle of "fine linen" and of "cunning work." The beautiful Helen of Troy put on garments of fine texture, embroidered by the maids of Sidon and colored with the purple of Tyre. These might have been sheer cotton fabrics. For in those days cotton was a stuff for rich and noble persons only. Until very recently, in fact, it was far too costly for any but the rich. Only for the past hundred years or so has it been so cheap as to clothe prince and pauper alike, in every quarter of the globe. And one of the main reasons why it can do so now is that a little over a hundred years ago a clever Yankee schoolmaster had the wit to invent the cotton gin.

In the circle is a portrait of Eli Whitney, inventor of the cotton gin, and below is a picture of the first cotton gin itself. It will be good news for amateur inventors that this famous machine's teeth were made out of bird-cage wire, and its rows of little brushes out of Mrs. Greene's hearth brush.

Photos by Gallery of Fine Arts, Yale University and the National Museum

Of course it was not the cotton gin alone that made cotton cheap. In some other stories we have told how the "spinning jenny" and the "spinning mule" and the power loom had come to spin out the threads and weave them into cloth much faster and more cheaply than human hands could ever do it. But cotton could never be cheap unless there was plenty of it, no matter how fast we could spin and weave it. And what the cotton gin did was to let us grow plenty of it.

Queer Cousins of the Cotton Plant

Now that is rather a long story. The cotton plant, which is so beautiful that it was once grown in our flower gardens, is a cousin to the hollyhock and the milkweed—whose coarse and crinkly pods, as nearly everybody knows, are full of delicate down. The cotton plant also bears a pod, called a "boll," and this is full of the downy fiber that we call "seed cotton." When the petals of the cotton blossom fall away, the boll grows fat with its swelling down and finally bursts into four or five divisions. Each division holds a "lock" of cotton.

Every lock of cotton contains several little hard, brown seeds. The thick fuzz, green-gray or white, that clings to the seeds is called the "lint." And lint is what we know as cotton. Now certain kinds of cotton have a long lint that is only loosely attached to the seeds. This cotton, probably first grown in India, was finally brought to the southern states of America, but there it thrives only in certain places in a few spots along the Atlantic coast and especially on certain islands near the shore. We call it "sea island" or "long-staple" cotton. But the common kind that grows all through the South and in many other countries is called "short-staple" or "upland" cotton because it was first grown in the rugged regions back from the coast. The lint from this is shorter, and it clings much more tightly to the seeds. Now the cotton gin is simply a machine to take the seeds out of the short-staple cotton.

Almost from the very start, we began to grow a certain amount of cotton in our southern colonies. The seeds were brought from the West Indies, from Italy and Egypt, and the gin we used for taking the seeds out of the lint was patterned after those that had been used in India for countless centuries. This gin looks a little like a modern clothes wringer and is called the "churka." It has

Photo by N. Y. Public Library

Even in the old days the life of laborers "way down south in the land of cotton" was often gay enough. Bending over their task as they carefully picked out the cotton seeds one by one, the slaves sang haunting songs now loved in many lands. Sometimes, as in our picture, they laid their work aside to strum the banjo and dance and sing to their hearts' content. And here come fine ladies from the master's house to watch the fun.

two wooden rollers, each about a foot and a half long, placed in a wooden frame and turned by a crank. The rollers do not quite touch; there is a space between them about wide enough to let through a very heavy blotting paper. When a lock of cotton is passed between these rollers, the lint may be pulled through, but the seeds will stay behind. Thus the cotton can be ginned, but only very, very slowly.

The Old Enemy of the Planter

From the outset this kind of gin made trouble for the American planters. The thing works pretty well with long-staple cotton, such as grows in India, but it is almost useless for ginning the short-fiber kind, the only kind that grows well in our cotton region. For the fibers are too short to be easily pulled through between the rollers, and the lint clings far too tightly to the seeds to come off readily. So the American planter had a bad time getting the seeds out of his cotton before he marketed it.

Of course he kept on growing a certain amount, because he had Negro slaves to take out the seeds by hand, at night, on rainy days, and at all other times when they were doing nothing else. He always had work for the Negroes, even for those who were still too small for any other job. But what a slow and tedious task it was! In the evenings, after the day's work in the fields was done, the Negroes would take home baskets of seed cotton to be cleaned by hand until bedtime. Sitting about in groups, singing, laughing, talking, they would pick out the shiny brown seeds one by one. And how little lint a slave could clean in an evening! Not much more than a shoeful, it was said. That would be less than a pound of lint in a day, or less than a bale of cotton for one person in a whole year. The future of King Cotton in America did not seem very bright. The climate was just right for the plant, the soil was suitable, and slave labor was abundant,

but hardly a planter could grow and clean more than one acre of cotton in a season. Little indeed was the cotton that reached the mills of England. And because it was so little, the price was high. Raw cotton cost as much as twenty-five cents a pound, and when it had been made into cloth it was so expensive that the poor could not afford it at all.

This was the state of affairs until almost the year 1800. Then, by a mere chance, the cotton gin, almost as we know it today, was invented by Eli Whitney, a young man from Massachusetts. Until the year when he invented his device he had never seen a field of growing cotton. Once he had made it, the planting and weaving of cotton soon became one of the world's great industries, the future of the crop in our own South was assured, and changes began that fill our histories.

Photo by A. C. Kelly Studio

Here is cotton falling into gin stands from extractor-feeder machines, where many revolving teeth have torn the seeds from the bolls. Four gins speed the job.

Eli Whitney was born in Westboro on December 8, 1765, and grew up to be a skillful craftsman and a mechanical genius. On his father's farm he mended the chairs and cart-wheels for the neighbors, and did all sorts of similar jobs. There is a story that even when he was a little boy he feigned illness one Sunday morning so that he might stay home from church and take apart the new clock that his father had just bought, while the family was away. For he had a passion for tools and for machinery of every kind, and he was cleverly inventive.

After graduating from Yale College in 1792, Whitney took a boat from New York to Savannah, where he was going to teach school. On the trip he found a friend in Mrs. Nathanael Greene, widow of the famous Revolutionary general; she took a fancy to the bright young man and invited him to make his home at the mansion on her great Southern plantation. There young Whitney was well liked by everybody, and especially by Phineas Miller, a Massachusetts man who was the superintendent of the plantation. Whitney quickly got a name for being able to "make anything," and this led to his inventing the first good cotton gin.

A Great Invention Made of Scraps

One day some planters from the uplands, guests at the Greene mansion, were lamenting that they could grow and clean so very little cotton. Whitney asked the reason. When he learned how hard it was to clean short-staple cotton he said he thought he could make a machine to do the work. So he set about it. He had very few tools, and he had to devise and make many that he needed for his task. He lacked certain materials, too, and for want of proper ones he had to use whatever was at hand. He even cut up a cage in which Mrs. Greene's daughter was keeping a pet bird—he needed the wire! At last, with his homemade tools and his makeshift materials, he carried out his plan. And it proved to be simple enough.

The first cotton gin was a boxlike contrivance about two feet square. At the top was a hopper with sides curved to fit over a cylinder beneath and notched into many

narrow slits. The wooden cylinder, turned by a crank, was set with rows of teeth made by driving short curved wires into the cylin-

der It was so placed that one row of teeth passed through each slit in the sides of the hopper. When the gin was finished, Whitney threw a handful of seed cotton into the hopper and turned the crank The wires tugged at the lint, carried it through the slits where it dropped into a basket below, and left the seeds behind in the hopper. This simple machine did the work of ginning rapidly and well. King Cotton was saved. Henceforth cotton was to be had by rich and poor alike.

On March 14, 1794, Whitney patented his invention. Soon afterward he joined with Phineas Miller in a partnership for making the machines. Then his troubles began. In 1796 a Georgian named Hodgen Holmes began to make a gin in which thin metal disks, notched like a saw, took the place of the rows of wire teeth on the cylinder of Whitney's gin. Whitney claimed that Holmes had stolen the principle of his invention, and took the matter to the highest courts of the land, but in the end he lost all the profit that he might have gained from his labors. Several southern states paid him small sums of money for his patent rights, but since cotton gins were soon made on every side, Whitney never made much out of the machines after that. But he grew rich in spite of all. He soon started to make firearms at New Haven, and was clever enough to amass a small fortune before his death on January 8, 1825.

From Whitney's time until this very day there have been fairly few improvements in the cotton gin, and none in its essential principles To-day, of course, the cotton gin is a huge machine, driven by steam or by electric power. Thousands of the machines are scattered throughout every region where cotton is grown. Ginneries, as they are called, are dotted all over the South. Just as soon as cotton could be rapidly ginned, the South began to plant it by thousands of acres. The year of Whitney's death, our exports of cotton were worth much more than all other exports combined.

Photos by Nature Magazine and the East African Dependencies

In these pictures we see King Cotton before and after his encounter with the cotton gin. At the top he is riding in state to the ginnery. In the center his hair is being skillfully combed clean of sticks and leaves and seeds. At the bottom he is waiting in snug bales to be shipped to the mills.

Reading Unit
No. 9

THE MACHINE THAT MADE BREAD CHEAP

Note: For basic information not found on this page, consult the general Index, Vol. 15.

For statistical and current facts, consult the Richards Year Book Index.

Interesting Facts Explained

How grain was reaped first of all, 10–409
The sickle and the scythe, 10-409-10
Why reaping wheat was very hard work, 10 410
How the reaper made work easy, 10-412
Cyrus McCormick succeeds with the reaping machine where his father had failed, 10-412-13
Reapers for the West made at Chicago, 10 413
The self-raking attachment, 10–413
A twine binder invented, 10 413

Things to Think About

How did the reaper help to make a new world?
Why was the harvesting of grain such hard work?
Why must the wheat crop be cut within ten days after it ripens?
How has the reaper helped us get our food?

Picture Hunt

Why was the work in the harvest fields very heavy in days gone by? 10–409-10
What were the chief advantages of the early McCormick reapers? 10 411

Related Material

Why were the English Corn Laws hated? 6–95, 12-442
Where is wheat grown? 9–98, 101
What diseases ruin wheat? 2–138, 140
Who planted wheat in the New Stone Age? 5–35
Name the different varieties of wheat, 9–98, 100
Where is wheat stored? 9-236
How did the American Indian squaws make their flour? 9-239
How is wheat turned into flour in our modern mills? 9 233-36

Summary Statement

With the coming of the modern reaper, workers could harvest ten times as much wheat as before, with the result that vast tracts of land were opened for its production. Immigrants flocked to North America and Australia to grow enormous quantities of it and bread was cheaper the world over.

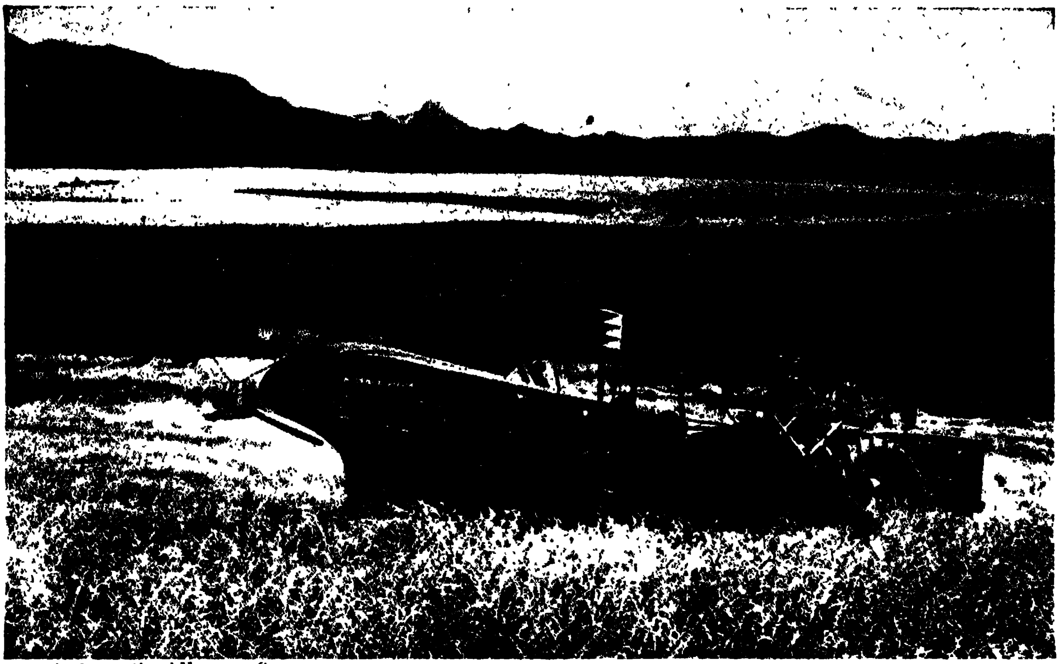


Photo by International Harvester Company

Under the shadow of mountains in the Gallatin National Forest this Montana farmer is using the "combine" that will cut and thresh his wheat—and clean the grain as well. A tractor, which he is driving, pulls the machine through the field and will also haul other machinery—plows, harrows, cultivators, weeders, and drills for planting. A big one will do the work of from 12 to 30 horses. All these devices save labor and so bring down the cost of food. Since they are costly, small farmers own them coöperatively.

The MACHINE THAT MADE BREAD CHEAP

This Will Tell How the Great Reaper Gave Us Ten Times More Wheat than We Used to Have a Hundred Years Ago

ANY wild animal spends just about all his time doing two things. He sleeps and he hunts for food. When he is not sleeping, he needs nearly all his time to get enough to eat. And that is about all he ever does.

A man is different because he does so many more things. The reason he can do so many more is that it no longer takes all his time to get enough to eat—as it used to, long ago in the beginning. And the reason why it no longer takes all of his time is that he has found out ways of getting so much more food than at first, and getting it so much faster. At first he had only the meat and fruit and grain that Nature grew for him, but now he can grow a thousand times as much as she ever supplied. And he can grow all these so easily that he has a great deal of time left over for other things.

Now this is the story of one of the great machines that he has made to help him get his food. It is the reaper. This machine cuts his grain for him; and his grain is probably his most important food, for out of it comes all his bread, and many of the other things he eats.

The first men who ever reaped a little grain must have simply pulled off the heads by hand. How long they went on doing that we do not know. But surely implements to help with their little crops must have been among the earlier inventions. There was soon some sort of knife to cut the grain—made at first, perhaps, of stone, and later of bronze. With a knife they could cut several stalks at once.

Then the knife was curved, or grew into a sickle, and still later it was made much longer and grew into a scythe. And these

were the best things we had to cut our wheat with for a long, long time—in fact until only about a century ago. Until that time, men were still cutting wheat just about the way they used to do it in Egypt.

Now when wheat is ripe it has to be cut fast. The whole crop must be cut in ten days at most. If we wait longer, it will break down and rot. So reaping wheat was about the hardest work that men and women and children ever did—for they all had to get out into the hot fields and hustle together. Some of them went ahead and cut the grain, leaving the stalks on the ground behind them. Others followed to gather the stalks and tie them into bundles, or sheaves. And still others came on and stacked the sheaves into shocks, to keep them from rotting on the ground or in the rain.

Photos by L. Ollivier

Here are peasants painfully harvesting the fields of France. The man is using the old-fashioned cradle scythe, and his wife has all the work of gathering the grain into bundles and tying it ready to stack.

Photo by Metropolitan Museum of Art

Before the long-bladed scythe was invented the sickle was the best thing men had to cut their grain. Here is an old, old one, its little blade well nicked with use.

It was furious work for everybody, for fourteen or fifteen hours of the long summer days. Many a back was aching, and many an eye of alarm was lifted to watch the weather. And when the toil was all over and the people dropped down to sleep like logs, they had only gathered enough grain to keep a few families going through the winter.

There is still many a small farm, mainly in rough, rocky land, where grain is gathered in this way, and where the old hard work is going on. But for many a thousand years all the wheat in the world was garnered in this toilsome fashion. No wonder the price of bread was high! For there was no use in raising a great deal of wheat—you simply could not cut it down in time, and it would rot on the ground.

Bread by the Sweat of the Brow

About the only improvement, till a hundred years ago, was the "cradle" for the scythe. This was a series of curved wooden prongs, or fingers, ranged about the steel knife of the scythe. As the grain was cut it fell in layers on these prongs, and the cutter

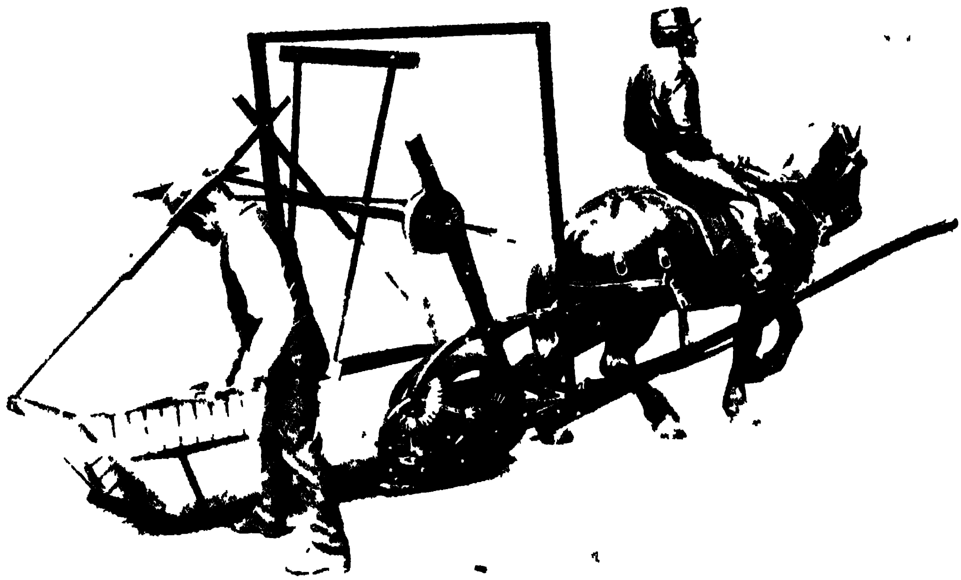


Photo by Science Museum, London

This is a model of the first little reaper that Cyrus McCormick tested in Mr. Taylor's wheat field in 1831. There had to be a boy on the horse and another man to rake the cut grain off the machine. Six more men bound the grain into bundles. That crew of eight could harvest twelve acres a day.

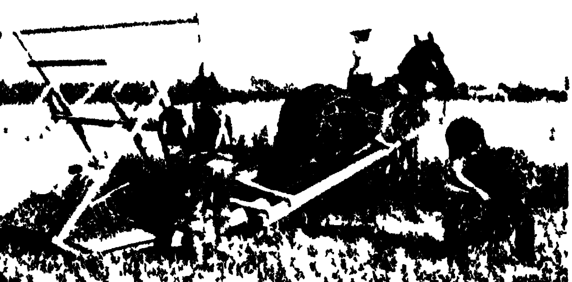
Photo by Science Museum, London

By 1851 McCormick had made his reaper into a thoroughly workable affair, and was selling it rapidly in Chicago. Now it had two horses, and seats for the two workers. But the cut grain still had to be raked off the machine to the ground and bound by hand; so a crew of some eight men was still needed.

could then lay it down in neater rows behind him. That meant less trouble for the binders who were following. But it was still terrible work to "bind behind a fast cradler" as the writer of these words can well remember from the hot days of his own boyhood!

And then came the great

In this little shop near Lexington, Virginia, Cyrus McCormick made his first reaper. Above it is a picture of the testing of that first machine. And at the right is a picture of the inventor when he had won fame at home and abroad and was the head of a great business enterprise.



Photos by International Harvester Co

reaper It made all the work easy It did the work ten times as fast, and so let us plant ten times more wheat And then the price of bread went down

The Vision of a Humble Blacksmith

In 1828 a Scotchman named Patrick Bell made a good reaper, perhaps better than anything we saw in America until some twenty years later. It had a long blade near the ground with a set of big teeth like the little teeth in a saw. Just above it was another blade with similar teeth. As it rolled along, the top teeth moved from side to side, over the lower ones, and cut down the grain just like so many pairs of scissors. The horses were hitched behind the machine and pushed, so as not to tread on the wheat; and a rotating wheel threw the grain to one side, so that the horses would not step on that either.

But this never made its way. If there were weeds or coarse grass in the wheat, they made trouble for the machine. And the farms in England were too small to need it, or often too hilly to use it well For of course a long, straight blade is hard to use on very rough land

In the year 1809 Cyrus Hall McCormick was born on a farm at Walnut Grove, in what is now the state of West Virginia His father was a farmer, and also a bit of an inventor, and he had a saw-mill and a blacksmith's shop on his own land For years he set his heart on making a reaping machine, and he put many of his ideas into wood and metal At last in 1831 the machine was made, though by that time the son was the inventor rather than the father In this machine the horses were in front, though not in the wheat, for the cutting blade swung out to one side behind them.

But it is one thing to start a machine, another to perfect it, and still another to get people to use it. At the very first public trial the machine failed, and the father cried

out bitterly, "I am through with it!" But the son went right on. A little later it was working better, and after a year of improvements, it had another public test. People came for miles to see it.

The Doom of the Scythe

A man named Ruff had offered his field for the test. At the very first, the reaper seemed to work badly, and Ruff cried out, "Stop your horses– you are ruining my wheat!" So things looked pretty bad. The people around began to make fun. But they wanted the machine to fail because they were afraid it would take away their work. They wanted to go on with a scythe forever! But just then a rather noted man named Taylor rode up. "Pull down the fence and go into my field," he called out; "I'll give you a fair chance!"

And on Taylor's level field the reaper flew along. At the end of the day it had cut six whole acres of wheat. And then it was hauled into the town of Lexington and shown in the courthouse square. "I thought it was a right smart curious thing," said one woman, "but that it wouldn't come to much."

At once Cyrus Hall McCormick set about making machines. By 1830 he had one that cut twelve acres in a day. But even at $50 each he had a hard time selling them. He finally sold seven in 1842, twenty-nine in 1843, and fifty the next year. Then he thought he saw success at last.

When some orders came from the West, he had no notion how to send out the machines. There was no railroad running west. So he started out himself to see the country, going by boat, stage, and horseback. For the first time he now looked on the vast prairies, and saw what his reaper could really do. In Illinois he saw great wheatfields too huge to cut, with the hogs and cattle trampling over miles of them.

Then he went home and made a new model, but he now knew the machines would have to be built in the West, where they were needed. So with great good luck he hit upon Chicago as his place. He had no money, but the mayor of Chicago, William Ogden, supplied the cash. Ogden put up $25,000 for a half interest in the business, and the factory was begun at once.

In the first year five hundred machines were built, and in the next year fifteen hundred. Then McCormick bought out Ogden for $50,000. He and his brothers now began to pile up a vast fortune.

The machine was steadily improved and perfected. When an invalid named Atkins saw a reaper working outside his window and invented a self-raking attachment, McCormick bought the idea. By 1874 came the invention that enabled the machine not only to cut the grain, but to bind it into sheaves. At first it used a wire for the binding, but the wire sometimes hurt or even killed the cattle that fed on the product. Then a twine binder was invented by John Appleby of Wisconsin, and McCormick bought this too. The machine went on improving until it grew to be the reaper that we have to-day, and the company that made it went on enlarging and combining until it became the present International Harvester Company, manufacturing all sorts of farm machinery to be shipped to all parts of the world.

The Empire Follows the Reaper

Enormous quantities of grain followed the invention of the reaper, and bread grew cheap all over the world. A great deal of time was saved from hard labor, for other work or for rest and recreation. The boundary of our frontier was pushed thirty miles farther west every year. Millions of men and women could come over from Europe to find homes in it. Great railways were built into the West, largely to bring back the wheat. In other lands, as in Australia, the reaper did similar things. Millions of people all over the world were better fed. And Cyrus Hall McCormick lived to see most of this happen, dying in 1884. He had helped to make a new world.

Reading Unit No. 10

OUR PERILOUS FRIENDS THE EXPLOSIVES

Note: For basic information not found on this page, consult the general Index, Vol. 15.

For statistical and current facts, consult the Richards Year Book Index.

Interesting Facts Explained

When nitrogen becomes restless and violent, 10-415

How gunpowder was discovered by accident, 10–416-17

When nitroglycerin was invented, 10–416-17

How Alfred Nobel found a way of making nitroglycerin useful, 10–417

How dynamite explodes, 10-417

T.N.T., one of the most terrible explosives yet discovered, 10 418

Blasting with liquid carbon dioxide and liquid oxygen, 10–418

Dust explosions, 10 418

Things to Think About

Why are violent explosives counted among man's best friends?

What will make other things besides explosives explode?

How has gunpowder changed men's lives?

What happens when the nitrogen in dynamite gets free?

Related Material

How is coal mined? 9–435, 440-42

How is copper ore removed from the earth? 9-419, 421

How was the Panama Canal cut? 10–269-74

How do we get marble out of quarries? 9-381

How do we explain the presence of volcanoes? 1-75-76

When is an oil well called a "gusher"? 9–450, 454

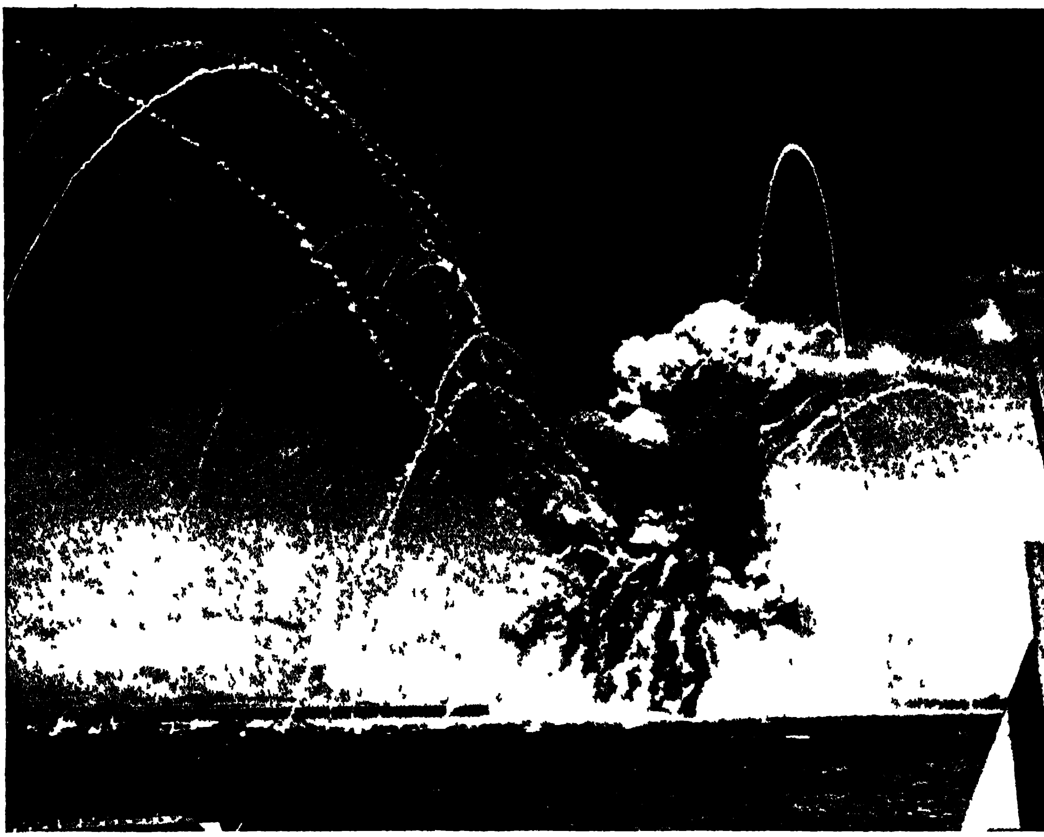
Practical Applications

How does the farmer use dynamite to help him in his work on the farm? 10–416

How are explosives used in road building? 10-416

Summary Statement

Explosives, which get their power from their ability to expand rapidly to several thousand times their original size, are among our best friends, but may become our enemies when used by an enemy country to bring about destruction in war time.



[illegible]

With the force of a small volcano a munitions ship has just blown up Its cargo of powerful explosives—stored into bombs and shells—suddenly has expanded to fill a space a thousand or fifteen hundred times its original size Billows of smoke mark the spot, and rocketing tracers lace the sky.

OUR PERILOUS FRIENDS *the* EXPLOSIVES

How We Can Pack Enough Power into a Little Cave to Blow Up a Whole Mountain, and What the Power Comes From

WHAT is it that happens when a thing explodes? Why will a stick of dynamite that is only about twice the size of a man's finger send a great stone flying through the air, or tear the strongest rock to pieces?

It is all because the dynamite has in it a good deal of nitrogen (nī′trō-jĕn) in a very restless state. Of course nitrogen is not always restless and violent, but only when it finds itself in company it does not like When it is perfectly free it is as harmless as anything in the world, indeed, it makes up about four-fifths of the air we breathe But when it is united with certain other substances, it is always ready to break loose with great violence if it gets the chance, and its best chance comes when it catches fire or meets with a jar Then it gets free, and in an instant it turns back into the gas it wants to be.

But a gas, as we know, is very thin and light and takes up a great deal of space So when the nitrogen in dynamite gets free, it needs several thousand times more room than it had in the dynamite—and it needs the room on the instant! So it helps itself to the space, no matter what is in its way, and we have an explosion that rocks all the neighborhood.

Photo courtesy E. I. Du Pont de Nemours and Co. Inc.

This jet of mud and gravel has been shot skyward by dynamite exploded by remote control. The well which the explosion has made would require long hours of toil if a pick and shovel had to do all the work.

That is all there is to an explosion. In nearly every explosive substance - gasoline, gunpowder, dynamite, TNT- the principle is the same. All of a sudden a gas has had a chance to get free into a much greater space; and if there is heat, too, it makes the gas need still more room, for heat makes gases "expand," or spread out.

And yet these violent explosives are among the very best friends of man so useful that the United States manufactures them by the hundreds of millions of tons every year.

Dynamite is used to dig ditches for drainage or irrigation or for laying a pipeline, to prospect for oil, to clear land of stumps and boulders, to loosen earth when we want to plant trees in an orchard or stop soil erosion, to settle highway fills in soft ground with the saving of several years as a result to sink wells, to make holes for posts and poles, to break log jams or ice jams that are causing floods, to exterminate mosquitoes by digging ditches for the drainage of swamps, to kill burrowing animals, such as woodchucks and gophers, to kill sharks for their leather, to stampede fish into seines, to demolish buildings or other structures either in clearing space or in stopping the progress of a city fire, to control forest fires, to blow out oil-well fires, and even to set rivets by expanding the bolt in its seat in that way saving a great deal of time.

Of course it is in war that we see explosives at their deadliest. There they are put to work in a great many murderous ways.

Their invention goes far back into the past, and clear around the world to China. But it is possible that in their present form they were first made by Roger Bacon, an English friar who may be called the first great modern scientist. Sometime before 1242 he seems to have accidentally discovered gunpowder, the first real explosive; for hidden away as a puzzle in one of his books is a formula he left us for making it. Of course the guns for using it still had to be invented, but in the next century they had begun to appear. For five hundred years gunpowder was the only explosive known. It is made of charcoal, sulphur, and saltpeter - and in saltpeter the uneasy nitrogen has been combined.

There are few things that have changed

Here are two of the many ways in which explosives are used to serve mankind. As you see in the top picture hills are blown away and valleys are filled in with the loosened earth to make the broad, smooth highways like the one under construction at the left. The miners below are placing

fuses in holes filled with dynamite. The coal thus blasted loose can be gathered quickly and easily.

Photos courtesy E. I. Du Pont de Nemours and Co. Inc.

men's lives much more than gunpowder. Armed with a gun, the weakest man was stronger than the mightiest knight in armor. And after powder and guns came, the knights soon went out of fashion.

It was not till 1847 that a new explosive was discovered. In that year an Italian chemist named Sobrero (sō-brä'rō) invented nitroglycerin (nī'trō-glĭs'ēr-ĭn), a heavy, oily liquid made by treating glycerin with nitric and sulphuric acid. The nitrogen from the nitric acid is so restless that nitroglycerin will explode at a slight jar— and without any warning. Yet under just the right circumstances it will burn quietly in the open air, and it is sometimes used as a medicine. But when it is confined, a shock or heat will send it off with terrific force.

It was not till 1866 that Alfred Nobel, a Swede—and the man who founded the famous Nobel prizes - found a way to make nitroglycerin useful. He soaked sawdust or wood pulp in it and then pressed the mixture into sticks. The result was dynamite, the most useful of all our explosives.

To set off dynamite one must strike it a hard blow. Then, with a tremendous bang, the nitrogen gets away. The nitrogen and other gases formed by the exploding nitroglycerin in the dynamite expand to ten thousand times their original volume. But dynamite does not burn as gunpowder does. It just "goes off" —or detonates (dĕt'ō-nāt).

We do not set off dynamite by giving it a direct blow. The blow is dealt by still another explosive - a much more sensitive one, such as tetryl (tĕt'rĭl) or lead azide (ăz'īd). A tiny bit of this is put into a small aluminum or copper cap which is exploded from a safe distance. This "primer" (prī'mēr) gives the shock that sets off the dynamite. Just after dynamite was invented, guncotton appeared. This is a terrible explosive, though it is nothing but plain cotton soaked in nitric and sulphuric acid and dried out. If we light the cotton it will simply burn away with a hissing sound. But if it is compressed and set off by a primer, it will explode and the gas will rush away at the rate of three miles a second.

A less violent explosive is needed to fire guns. Various kinds of smokeless powder, which was first invented by a Frenchman in

Photo by U S Coast Guard

With a tremendous roar the explosive will shatter this mountain of ice, and the fragments will float harmlessly away, to melt in warmer waters. It is the business of boats in the United States Coast Guard, as this one is, to shatter icebergs reported in American waters, for icebergs are dangerous to ships

1887, are used in all armies today They are called propellants, and are usually made of some explosive like guncotton mixed with other substances If they banged suddenly the gun would burst or be otherwise ruined. But when a smokeless powder, like cordite, is used, the shell is given an easy push at the start and is then sent out faster and faster till it flashes from the muzzle of the gun at dizzy speed

And this is important because the shell itself is filled with a powerful explosive This substance is set off either by a time fuse in the shell or by the shock of hitting the ground TNT is the nickname given to the most common high explosive used in shells Its real name is trinitrotoluene (trī-nī′trō tŏl′ū-ēn). Only since 1900 has it been used in shells When it is pure it is very safe, and has long been used in making dyes TNT mixed with cyclonite makes the still more powerful RDX, widely used during World War II in bombing European cities

When combined with ammonium nitrate TNT makes an explosive called amatol, which has been widely used for filling shells Coal miners mostly use ammonia dynamite or gelatin dynamite for these do not set coal dust and gas on fire Gelatin dynamite most powerful of all industrial explosives is made by dissolving guncotton in nitroglycerin Liquid carbon dioxide (dī ŏk′sīd) is used for the same purpose In 1899 liquid oxygen was first used, for blasting out the famous Simplon tunnel in Switzerland All explosives approved by the U S Bureau of Mines for coal mining are known as "permissibles"

Other things besides explosives will explode The dust in a coal mine can "blow up" The fumes from gasoline will burst into flame and drive gas engines The gas from a gas stove will flash out with a bang But these things must have oxygen before the explosion can take place, for the flame that causes it must have oxygen to burn All common explosives contain a compound which, on being heated, breaks down and provides the oxygen needed For this reason they do not depend on the presence of air.

Reading Unit No. 11

OUR FINGERS AND OUR FIGURES

Note: For basic information not found on this page, consult the general Index, Vol. 15.

For statistical and current facts, consult the Richards Year Book Index.

Interesting Facts Explained

Why numbers are the same all over the world, 10-420
The way men found to write numbers, 10-421
How the Babylonians counted, 10 421
Greek and Roman numbers, 10-421-22
How we got our numbers from the Arabs, 10-422-23
Why we call twenty a "score," 10 423
How algebra is a short cut in counting, 10-424
Machines that do our counting for us, 10-425-26

Things to Think About

Why did it take the Arabic numerals a long time to replace the Roman ones?
Why did people count by scores?
Why was algebra a very important invention?

Related Material

What do we know about the Father of Geometry? 13 373-74
Of what use to us is the calculus? 13-520
What do algebra and geometry owe to Descartes? 13-13-14, 108-9
What great scientist invented a new kind of clock? 13-377
Was Newton interested in mathematics? 13 400
What use did Ohm make of mathematical calculations? 1-515-16
What is a "watt"? 1-509-10
How is Greenwich time used to reckon longitude? 10-459

Practical Applications

What saves modern bookkeepers a great deal of time and trouble? 10-426
What different ways can we use to count things? 10-423

Leisure-time Activities

PROJECT NO. 1: Make a chart to show some of the ways in which men have written numbers, 10 422
PROJECT NO. 2: Make an abacus, 10 423, 425

Summary Statement

All of mathematics is based on counting, but as man advances he finds out a great many different kinds of things to count and a great many different ways of counting them.

Photo courtesy International Business Machines

Figures of any kind are no trouble at all for the machines you see in this picture. The large electric one in the center, for example, is a wizard at numbers. It can add, subtract, classify, and work out all sorts of totals. It prints and prepares records and reports on cards that are fed to it correctly. It can do things human beings can't do, and it works much faster but human beings still are needed to operate it.

OUR FINGERS *and* OUR FIGURES

This Is the Story of All Our Ways of Counting. Did You Know that You Use the Decimal System because You Have Ten Fingers?

NUMBERS are the same all over the earth—even more so than the fingers on which so many people count them. If you were in China and wanted half a dozen eggs, you might not know how to ask for them; but you could point to the eggs and hold up five fingers of one hand with one finger of the other. You would get your six eggs. And the same thing would happen in Mexico or Madagascar or anywhere else. The names of the numbers would all be different, but the numbers they stand for are the same all over the world. In a pinch, fingers will always do.

Now the early people learned to count on their fingers just as children often do to-day. Even now we can find the natives in Africa counting first on one hand and then on the other. Of course they do not go very high, but they can count as far as they need. They have little to buy or sell, no rent to pay and no money to bank; so they need no higher mathematics. If they want to remember their numbers they make a few notches

on a stick or scratches on a stone. That is all the bookkeeping they do.

When people had learned how to write, they soon found a way to put down numbers. At first they just made some sort of plain mark—/// for three and ///// for five. But of course they could not write any very large numbers in that fashion. So the earliest writers that we know, the Egyptians, soon invented a special mark for ten—it was like a U turned upside down. They could make plain marks up to nine, but then they would start over again. ∩ was ten, /∩ was eleven //∩ was twelve, ///∩∩∩ was thirty-three, and ////∩∩∩ ///∩∩ was fifty-seven.

These were all such simple signs that any Egyptian could read them and keep his accounts, even though he could not read and write the language that he spoke.

But not all the old peoples were so clear. The Babylonians had a harder way of writing numbers. Here is a Babylonian number:

▼ ▼ ◂◂ ▼ ▼

Can you tell how much it is?

It looks like six arrowheads pointing different ways, because the Babylonians wrote by making wedge-shaped marks in soft clay. The number here is 142, and this is the way to count it: 60 + 60 (the first two big arrowheads) + 10 + 10 (the two little arrowheads) + 1 + 1 (the last two big arrowheads) = 142. The same big arrowheads stand for sixty or for one, according as they begin or end the number.

The Babylonians used to count by sixties instead of hundreds, just as we count our minutes and seconds on the clock to-day. In fact, we may have got our sixty seconds and our sixty minutes from their way of counting.

Photo by Metropolitan Museum of Art

Men have ever felt that numbers held something of the world's mystery. Pythagoras, the Greek philosopher, made a religion out of them. Plato and many another thinker have spoken of God and creation as the One and the Many. There have always been sacred numbers, such as three and seven. Even more mystery lies in "infinity," which is vastness beyond numbers. Something of this sacred mystery is expressed in the beautiful figure above, which comes from an Egyptian tomb of about 500 B.C. Its meaning is "millions of years."

Aside from Babylonian sixties and Egyptian hundreds, there have been and still are many other ways to count. Some tribes have counted by fives, because we have five fingers on each hand; some by twos, because we have two hands and feet, two eyes and ears; and some, like the Eskimos, by twenties, because we have twenty fingers and toes. But most Europeans have always counted by tens, like the Egyptians, because of the ten fingers on the two hands.

Thus the Greeks, who learned from the Egyptians and Phoenicians, took ten for their basic number; but instead of mere marks for one, two, three, and other numbers, they used letters from their alphabet. The Greek word for "five" began with the letter *p*, or π, and the letter stood for "five." The word for "ten" began with *d*, or δ, and that sign stood for "ten." And so on for all the other numbers, with combinations as they grew larger. Of course this was fairly clumsy, and it was pretty hard to do arithmetic in Greek.

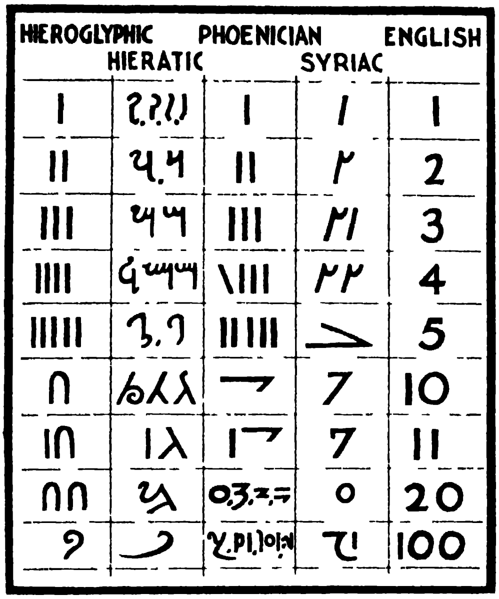
The Romans used a few plain marks and a few letters with them, and made up a system that was a good deal easier. For one,

two, and three they used plain marks. For five they used a V, which seems at first to have been the picture of a hand, and for ten they used two of these, one of them upside down, like this:

V
Λ

In time this sign became an X. For fifty they employed L, for a hundred C, for five hundred D, and for a thousand M. With these few signs they could write their numbers.

But they still had some further tricks. They never used more than three straight marks together I, II, III for one, two, and three. Four was IV, or one from five, and nine was IX, or one from ten. So XC was ninety, or ten from a hundred. The Romans wrote "ten from a hundred" for ninety just as we say "a quarter to twelve" for "forty-five minutes after eleven."



This table gives some of the ingenious ways in which men have written numbers. Of the two systems at the left, both Egyptian, the hieratic gave many hints to the Phoenicians and Syrians. But none of them looks much like the English —or rather the Arabic, if we are to give the credit to the people who introduced it into Europe.

Did you ever try to add and subtract in Roman numerals? It looks hard until you try it, but then it proves fairly easy after all. This is about the way a Roman schoolboy did it:

	X	VII	=	17
	XX	IV	=	24
	LXXX	VIII	=	88
	XXX	III	=	33
C	LX	II	=	162
	(Carry C)	(Carry XX)		

The boy separated the units from the tens just as we do. Then he added up—maybe on his fingers!—and "carried over" just in our way. In this sum he carried XX (twenty) over from the units, and C (a hundred) from the tens. He could do this pretty fast.

The Roman numerals were better than the older ways of counting, and they remained in use for nearly two thousand years. As late as the end of the Middle Ages scholars could still add and subtract in the signs that had come down from ancient Rome.

Yet long before that time we had far better numerals - the ones we are still using to-day. And these came from the Arabs. But the Arabic numerals did not by any means replace the Roman ones all at once. In fact they took several centuries to do so, and in the meanwhile the two systems lived on side by side, with one slowly losing and the other slowly gaining. For when men have learned to count in one way, it is pretty hard to get them to use any other If we suddenly discovered now that the Chinese had a better system of counting than we have, do you suppose we should take it over to-morrow? By no means. In fact, we are still refusing to take over the French way of measuring and weighing the "metric system" though everybody knows it is better than ours.

The Arabs' Gift to Europe

So although the first manuscript in Europe to use Arabic numerals comes from the year 976, the arithmetics were still explaining the Arabic system very carefully as late as 1500, because people had been so long used to Roman figures. But finally the Europeans took to the counting system which the hated Arabs, or Moors, had brought with them when they came over from Africa and conquered Spain. And once their numerals were fully adopted, the Roman ones were gone forever - though they still linger on the faces of some clocks, in inscriptions on some churches, in the chapter num-

bers in certain books, and in a few other places.

These numerals were not really invented by the Arabs. They first came from the Hindus in India, who were skilled in mathematics as long ago as the year 200. And the numerals as the Hindus wrote them look a good deal like the ones we write to-day. They taught these numerals to the Arabs, and the Arabs passed them on to us.

What Is a "Score"?

We are all so used to the decimal system that we often feel it is the only natural way of counting by tens. But in the older days of Europe there were other ways of doing it. For instance, the old Franks liked to count by twenties. Whenever they passed twenty they made a mark or a score, and that is why we still call twenty a "score." So "three score years and ten" are three twenties plus ten, or seventy. And the French to-day say "four twenties" instead of "eighty," and "four twenties ten" for "ninety."

But twenty is too big to be convenient, and ten is a good deal better. It is by no means the best unit, however; and in fact our decimal system, good as it is, remains inconvenient. For twelve would be the best unit to use, and a duodecimal (dū'ō-dĕs'ĭ-măl) system—counting by twelves—would be a great improvement on the decimal one. The reason is that ten can be divided only by two numbers, two and five, while twelve can be divided by four two, three, four, and six. So we could count and keep books a good deal better if we went by twelves instead of tens.

The mathematicians have known this for a long time, but what chance is there of getting people to change? It would be ten times harder than it was to get them to take over the Arabic numerals. And yet we all use the system a little bit. Nobody ever buys ten eggs; he always gets a dozen. And nearly all commercial stocks are counted by the dozen or by the gross—which is twelve dozen.

Tallies like this were much used during the Middle Ages to record debts. Every notch means a certain amount of money. When the notches had been made, debtor and creditor would split the stick into two parts, each taking one. Then if they quarreled over the amount of the debt they could put the two parts together and see if they "tallied."

When people have once learned how to count, they soon need to do a little more. They need to add and subtract, multiply and divide, and do still other things with their numbers. So arithmetic is born, and we are not surprised to know that it is a very old science. Of course people did a good deal with arithmetic before any book was ever written about it. But a book of arithmetic was written in Greece by the famous mathematician Euclid (ū'klĭd), about twenty-three hundred years ago, and another by the great astronomer Claudius Ptolemy (tŏl'ē-mĭ) in the second century after Christ. By this time people could do very hard problems in arithmetic.

And by this time they had also gone a good deal farther than arithmetic. All of mathematics is based on simple counting, but as man advances he finds out a great many different kinds of things to count and a great many different ways of counting them. For instance, he learns to count all sorts of angles, triangles, squares, cubes, and other figures—because he has to know these things if he is going to survey his land, to build pyramids, and to do many other things. And as soon as he begins counting and measuring such things, he is beginning geometry.

Father Nile, the Egyptians, and Euclid

The old Egyptians learned a good deal of geometry. It is often said that they had to do so; for the Nile overflowed every year to wash out all their boundaries, and in order to mark the boundaries off again they had

to know something about angles and other figures. However that may be, we know that the great Euclid in Greece learned all he could from the Egyptians and with what he added became the most famous man of all time in geometry. He wrote down nearly all there is to know about the subject; and to this day the boys in England who are studying geometry say they are beginning "Euclid."

What Is Algebra?

As people went on counting, they came in due time to algebra. It was a very important invention. We have seen how convenient it is to write down figures, instead of letters of the alphabet, for our numbers. But in algebra we have found a short cut in counting by reversing the process—and we actually use letters in the place of figures. Sometimes when a large number has to be repeated many times, we just call it *a* for short; and if there are several such numbers, we call them *a*, *b*, *c*, and so on. Sometimes when we do not know what a number is, we simply call it *x* until we can find out. Until then it is an "unknown quantity"; and if we have several of these, we can call them *x*, *y*, *z*, and so on. The business of algebra is to find out what X is; and the answer always comes out in figures.

How Algebra Works

For instance, suppose you had 81 cents and wanted to divide it with your brother so that you would have twice as much as he has. Let X be what he gets; then $2X$, or twice that much, will be what you keep. But $X + 2X = 81$, which is to say that $3X = 81$. Now divide by 3, and you find that $X = 27$. Then $2X = 54$. So you would give your brother 27 cents and keep 54.

The expression "$X + 2X = 81$" is an equation, with 81 for the known quantity and X for the unknown one. All algebra works by equations. Of course this one is very simple, but sometimes they are long enough to cover a whole blackboard and hard enough to take days or weeks to solve

Algebra was studied for centuries by the Egyptians, Greeks, Romans, Arabs, and other peoples, but it was not really perfected in our form until the time of Descartes (dā'kart'), a Frenchman who died in 1650. We get its name from a treatise on it written in Arabic about eleven hundred years ago, and called *Al-jebr.*

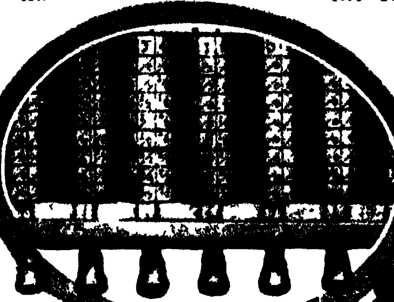
Once Darius the Great had to leave some of his Ionian allies to guard a floating bridge in his absence; and this is what he said to them: "Men of Ionia, keep this thong and do as I shall say: so soon as ye shall have seen me go forward against the Scythians, from that time begin and untie a knot each day; and if within this time I am not here, and ye find that the days marked by knots have passed by, then sail away to your own land!"

If you are pretty good at algebra, you might crack your wits at the following problem. A column of soldiers one mile long advances one mile. Just as the column starts, a courier leaves the rear, goes to the front, and returns to the rear, arriving there just as the column stops. How far has the courier gone?

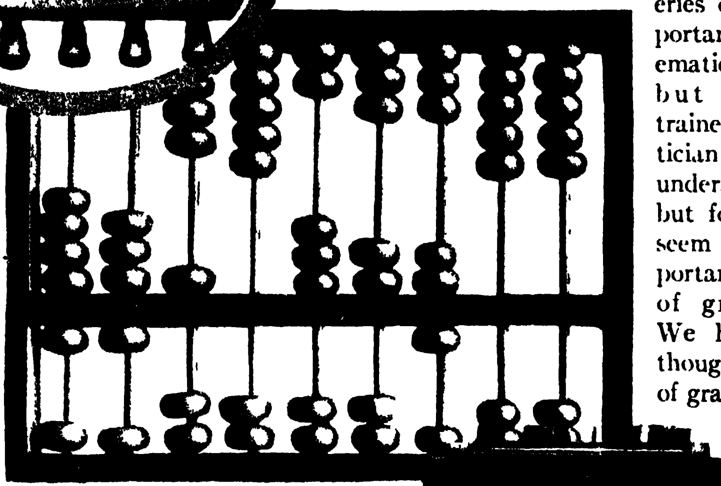
There are still higher ways of counting than by algebra. There is trigonometry (trĭg'ō-nŏm'ē-trĭ), which has also come all the way down from Egypt, and which goes beyond the ordinary diagrams of geometry into complicated formulas. It is useful to men who steer boats and make maps, and for many other purposes. There is analytical geometry, which is the study of complicated curves—useful to engineers and many other workers. And there is the calculus, or the study of quantities that are always varying. Beside these there are many other great branches of mathematics—so many that the most brilliant man, working on them all his life, can hardly master them all. And that is what has come out of what we started when we first began to count, long ago.

All of these ingenious inventions we owe to the thousands of men who have worked at them, before the days of Euclid and Ptolemy and ever since that time. Such a man was the great Descartes, who gave us analytical geometry in 1637. Such were Leibnitz (lĭb'nĭts) and Sir Isaac Newton, who both invented the calculus about the same time—around 1686. Such were Kepler and Pascal and Napier, in the same century.

And such a man, to name no others, is Albert Einstein (īn'stīn) in our own day. For after all these centuries it has been left for Einstein to make some new discoveries of great importance in mathematics. No one but a highly trained mathematician can possibly understand them, but for him they seem to be as important as the law of gravitation. We had always thought the law of gravitation was about the surest thing we knew, but Einstein seems to have found a little fault in it to be corrected. For this and other exploits he is about the most famous man in the world to-day. He is our greatest "counter"—what a long way from the Eskimo, figuring on his toes and fingers!



At the left is a set of "Napier's bones," in handy cylindrical form. In the lower corner to the right is a set in the original form, arranged for multiplying 765,479—the number across the top—by 6.



American children often learn to do simple sums with the help of an arrangement of sliding beads like that above. Did you know that the contrivance had a dignified name, "abacus" (ăb'ȧ-kŭs), and was really the first adding machine? It is still in everyday use in the Orient.

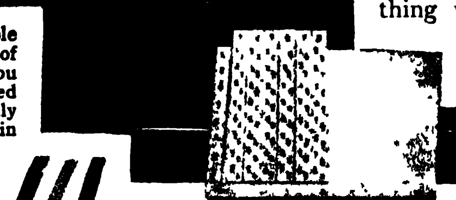


Photo by Science Museum London

Machines That Do Our Counting

We now have machines for everything, so of course we have them for counting. We can add and subtract, multiply and divide, by punching keys and pulling levers—and

we can do it faster, with less chance of error.

It was the great Pascal who made an adding machine as long ago as 1642. Since that time the machine has been greatly improved and made to do more things, but its principle is always the same at bottom. For it rests on solid numbers, and these do not change.

How an Adding Machine Is Made

If we take a little wheel and divide it into ten parts, we shall have the beginning of an adding machine. Suppose we start with number 1 at the top of the wheel. Now if we turn the wheel three parts around we shall have number 4 on top, $1 + 3 = 4$. If we turn it three parts more, we shall have 7. So we can get up to ten with one wheel.

If we have a larger number, we need only put several other wheels alongside the first wheel. When the first wheel turns all the way around—up to ten—it will make the second wheel turn one part, or one-tenth. It "carries over" one to the next wheel, just as we carry over one from the units column to the tens column in adding. In the same way the second wheel can "carry over" into the third, which represents the hundreds column; the third into the fourth, or thousands column, and so on. And the machine writes it all down, with the sum, just like a typewriter. There are big machines to-day that run by electricity and add as many as seventeen columns.

Of course if they can add they can multiply too, for multiplying is only repeated adding. So 4×7 is only $7 + 7 + 7 + 7$, or 28. And 472×3 is only $2 + 2 + 2$ and $70 + 70 + 70$ and $400 + 400 + 400$, or 1416; as any adding machine will show, for that is the way an adding machine does the work. It can subtract too, and do a little division.

About the same time that Pascal was making his adding machine, the Scotchman Napier was inventing his multiplying rods. The different multiplication tables were printed on sticks of wood in such a way as to show the product of any numbers at a glance. But of course the numbers had to be written down by hand, and therefore "Napier's bones," as his wooden sticks were called, though exceedingly ingenious were less useful and accurate than Pascal's machine.

Since that day there have been many varieties of adding machines, though they are built upon the same idea. Only since 1802 have they been printing the figures and their total. Such machines are found in every bank and big office. But machines that merely add seem old-fashioned in today's world. There are several giant electronic calculating machines that do all the arithmetical processes and solve the most difficult problems of higher mathematics. In an hour they can save a man months of steady labor.

The adding machines that we most often see are not called adding machines at all. One of them is the cash register we find in nearly every shop. Yet the cash register can add and give the total of all the money that is put into it during the day. It prints a record of every sale, and shows exactly how much cash is in the drawer at any moment. Another adding machine is the speedometer in every car. At any moment it will tell you how far the car has gone.

But one of the most remarkable devices for calculating is not a machine, but a simple rule. It is called the "slide rule." It has several different scales printed on it, and a little wooden bar that slides back and forth over it. With this we can not only multiply and divide, but we can calculate compound interest and do problems in arithmetical progression. It was invented in 1654 and has been a help to accountants and engineers ever since.

If we have machines to do all these things for us, why do we work so hard to learn arithmetic? Why not let the machines do it all? Well, because we could never work the machines unless we knew all about figures ourselves. But still more because it is far more important to have a good head than to have the best machine ever known! Once we have the head, we can set the machine to work when we like, but without the head there would never be any machine at all. And then we are not through with mathematics yet, for there are still all sorts of discoveries to be made—by the Euclids and the Einsteins of the days to come. We still have plenty to learn about "counting."

MAKING MATHEMATICS EASY

Reading Unit
No. 12

Note: For basic information not found on this page, consult the general Index, Vol. 15.

For statistical and current facts, consult the Richards Year Book Index.

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Things to Think About

What are the "Arabic numerals"?
What important rules must we learn if we wish to avoid making mistakes in mathematics?
What is the meaning of the terms used in algebra?
Of what use is geometry in everyday life?
What things have we made after geometrical forms?
Why is a clock especially useful in our study of angles?
What will make us hate "sloppy thinking"?

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Summary Statement

Because mathematics teaches us to think clearly and accurately, we learn to hate "sloppy thinking" and to avoid "jumping at conclusions."

Photo by J C Allen & Son

It is amazing how much pleasanter school is when one does each day's work as it comes along Then nothing seems very hard, for nothing is very puzzling. That is because, both in school and in life, to-day's work is the foundation of to-morrow's accomplishment The young people in the picture above would hardly look so happy if they had not done their homework thoroughly and well School has no terror for them.

MAKING MATHEMATICS EASY

A Few Hints for Smoothing the Way in a Subject that Has Caused a Good Many Heartaches

IT IS a great pity that anyone should go through school without ever finding out that mathematics is fun Those rows of signs and numbers, so neat and sometimes so stubborn, can march along with the perfect precision of a column of soldiers, or they can be as unruly as a crowd of boys just let loose from school Keep them well under control and they will perform your every command. But once lose your mastery of them, and your life will be a burden every time you call upon them to do some necessary piece of work.

The advice that follows is set down in the hope that parents and teachers, or elder brothers and sisters, may be helped to show young learners how to grasp each step in mathematics as it comes along and so to have a firm mastery of the subject from start to finish With that mastery will come a sense of pleasure that will be worth any amount of pains Mathematics will have become a fascinating game

The young learner who has already lost his way in the subject may be helped, also He must be taken over all the beginning steps again and again, and always with the greatest gentleness and patience Try to see that he never makes a mistake in what he learns, and that he forms the priceless habit of taking pains

The tiny tot's first step in mathematics is to learn the ordinary number signs what we call the "arabic numerals" (ăr'ā-bĭk nū'mēr-ăls) 1,2,3,4,5,6,7,8,9 Of course, he will learn them in order, or, as we say, he

will "learn to count." And that he may get a clear idea of what a given number means, he will learn to count by counting objects. These objects may just as well be interesting and pleasing in themselves—marbles, flowers, or small pieces of candy. Our little pupil's first association with numbers can be made agreeable or tiresome by the choice of the objects he has to handle. The child will first learn to assemble any given number of objects up to 20, and later up to 100. He must be able to say at once which of two numbers is the greater, and to recognize and write the arabic numerals for all of them. He will arrive at these accomplishments through his normal play, and later through special programs provided for him by the school. Such games as flinch, throwing at a target, bouncing a ball, jumping rope, will give good practice in counting. And daily reference to a calendar will entertain and instruct him.

But for the next step all games which lead to haste or excitement are bad. Our little arithmetician must now learn by heart the hundred addition and hundred subtraction facts, such as that 9 and 5 are 14, or that 6 from 13 are 7. It is important at this stage to keep him from making mistakes. He must practice and learn to remember *facts*, not errors. Hurry and excitement encourage errors, whereas what he must have is the greatest possible precision.

The one outstanding stumbling block for children in the early years at school- and for some students even in high school or college is the failure to master the hundred simple addition facts and the hundred simple subtraction facts. This leads directly to the "counting habit." Usually the trouble began during the first few months of number work at school. A few children get a bad start even before they go to school, for they are allowed to play at adding by counting. It is dangerous to a child's future progress in arithmetic to trust that he will "pick up" these simple basic facts. He must learn them by rote. After he goes to school the counting habit and the habit of making mistakes are certain to be prolonged by the atmosphere of hurry that prevails in some schoolrooms. Especially bad are speed drills and stop-watch exercises.

Now there are a few precautions that, taken at the start, will keep our lad or lass from falling into these pitfalls. We shall list them here:

1. Do not have the child learn the simple addition and subtraction facts by counting objects. On the contrary, let him learn by rote that 9 and 6 are 15, for example, or that 2 from 11 leaves 9. He will learn them as mechanically as he learns to spell "cat." Use the form

$$\begin{array}{r} 9 \\ 6 \\ \hline 15 \end{array}$$

2. Let him learn each number fact before he uses it in a verbal problem. Then let him have a chance to use it frequently in interesting problems, in order to fix the number fact in his memory.
3. Have him attack only a few of these facts at a sitting, after he has first drilled himself on what he has already learned perfectly. Help him to hold fast all that he has learned. Let drill always mean over-learning of things already learned, and not corrections of errors. Allow no mistakes to occur! This may sound strange, but it is entirely possible to do if the number facts are taught very slowly and with constant repetition. Encourage the child never to guess or hurry.
4. Have him learn those number facts first which are not easily counted, such as

$$\begin{array}{rrrrrr} 8 & 7 & 6 & 5 & 4 & 9 \\ 7 & 8 & 5 & 6 & 9 & 4 \\ \hline 15 & 15 & 11 & 11 & 13 & 13 \end{array}$$

Such combinations as

$$\begin{array}{rrr} 1 & 2 & 3 \\ 1 & 1 & 2 \\ \hline 2 & 3 & 5 \end{array}$$

will come relatively late, for these merely tempt the child to count.
5. Keep your little pupil at easy addition until the hundred simple addition facts are mastered. Then he may begin subtraction, learning it in the same way in which he learned addition. When he is learning subtraction do not shift often from one process to another. In that way you will keep the child

from subtracting when he is supposed to add or from adding when he is supposed to subtract – a very common type of error.

6. Later have him learn the multiplication facts – and not in order, but like this:

$$\begin{array}{cccc} 8 & 6 & 3 & 5 \\ \times 3 & \times 9 & \times 4 & \times 7 \\ \hline 24 & 54 & 12 & 35 \end{array}$$

7. Avoid all speed drills and suggestions of haste. Make accuracy the goal. Published scientific studies prove that emphasis on accuracy furthers speed and accuracy, while emphasis on speed retards speed and reduces accuracy.
8. In taking up harder addition and subtraction, move very gradually from the very simple to the slightly more complex. Provide the child with samples done clearly, step by step, on paper or the blackboard, and leave the models for him to refer to when he likes. The secret of success is in taking each new step very slowly and in mastering it thoroughly before another step is attempted. Always let the problems be short ones, especially in the early learning stages. Your slogan must be, "Simplicity and Accuracy."
9. Never dictate a verbal problem. Have it clearly written on the board, multigraphed, or printed. Such a problem should have a strong emotional appeal, and should not be made painfully brief. Persuade the child to read the problem very carefully before he tries to solve it. Let him work in an atmosphere of serenity. In the first three or four grades the problems should be "story problems" with a powerful imaginative appeal. Later they can well be fact problems but still with an appeal to the imagination. Let the facts used be interesting facts of all sorts gathered from newspapers, magazines, and encyclopedias.

Long Division

The dread of many a child—and of many a teacher-- is long division. Yet it can be made easy. Before you introduce long division to a pupil make sure that he has already mastered the ninety-six basic multiplication facts and the hundred subtraction facts. He must thoroughly understand the process of multiplying and subtracting. Make sure, besides this, that he can tell at once on sight that one number is smaller or larger than another -that, for example, 25 is more than 23, 407 is more than 396, 589 is less than 610, and so on. Don't shame or scold him if he has failed in any of these things. Patiently show him how to master them.

Teach long division before short division. Make it very simple and easy. Begin like

 2
this: 4)8 After he has practiced on several
 8

like this one, move to the slightly harder type,

 2
3)7 Later go on to slightly harder ones still,
 6
 1 rem.

 17
such as 5)85 Think aloud as you proceed
 5
 35
 35

very slowly. Let the child have several learning periods in long division before you intro-

 3
duce a problem as hard as 21)63 How
 63

fascinating long division thus becomes! After the child has mastered long division he can learn short division easily in a few minutes, for it is merely a short cut to long division.

Common Fractions

At play with toys and tools a child, even before he enters school, uses the simple fractions halves, quarters, thirds, and eighths. If he keeps on using his spare time to make things with his hands, he will at the age of twelve or fourteen have found out a good deal more. The boy or girl who handles tools, who follows or draws up or modifies patterns or recipes in which paper, cardboard, wood, cloth, or foods are used, must necessarily pick up nearly all the fundamental ideas about fractions and denominate numbers – and may even develop a good deal of skill in handling them.

Now in common fractions there are certain simple notions on which everything else rests. Our boy or girl must grasp the fact that the value of a fraction decreases as the size of the denominator is increased; that it increases as the size of the numerator is increased; that only fractions with the same denominator may be added or subtracted. And of course it will be necessary for him to know how to change fractions with unlike denominators into fractions with like denominators.

As was true of whole numbers, it is well to practice a long time on the simplest, much used combinations. Begin by adding or subtracting in the form $\begin{array}{r}\frac{1}{3}\\ \underline{\frac{1}{3}}\end{array}$, $\begin{array}{r}\frac{3}{4}\\ \underline{\frac{1}{2}}\end{array}$, $\begin{array}{r}3\frac{1}{2}\\ \underline{2\frac{1}{4}}\end{array}$ before using the forms $\frac{1}{3}+\frac{1}{3}$ or $\frac{3}{4}-\frac{1}{2}$

When the child is confused in handling measurement, not knowing whether to divide or multiply in changing quarts to pints or inches to feet, let him have practice in making the actual measurements. But don't hurry him while he does it. Let him be happy and serene, without any feeling of shame at his ignorance Otherwise he will probably get nowhere with it. Let him have leisurely practice in writing out such equivalents as these:

24 inches	=_	feet
3 quarts	=	pints
½ hour	=	minutes
15 minutes	=	hours

Decimals

Decimals are not hard when they are carefully taught Let the learner first have practice in reading and writing whole numbers as long as 3,476. Then in order that he may gain the basic principles of decimal fractions, place before him such samples as the following:

	Common fractions	Decimal fractions
Sixty-seven hundredths	67 100	67
Three hundredths	3 100	03
Seventeen and nine hundredths	17 9 100	17 09
Four hundred twenty seven thousandths	427 1000	427

When a whole number is followed by a decimal, the decimal point is read as "and "

	Hundred Thousands	Ten Thousands	Thousands	Hundreds	Tens	Units	Tenths	Hundredths	Thousandths	Ten-thousandths	Hundred-thousandths	
a						8						Eight
b-					3	7	4					Thirty-seven and four tenths
c				6	0	7	2	3				Six hundred seven and twenty-three hundredths
d			4	3	1	0	0	7	8			Four thousand three hundred ten and seventy-eight thousandths
e	3	2	6	4	8	7	1	0	5	6		Three hundred twenty-six thousand four hundred eighty-seven and one thousand fifty-six ten thousandths
f	7	2	0	5	4	8.	0	9	7	8	4	Seven hundred twenty thousand five hundred forty-eight and nine thousand seven hundred eighty-four hundred thousandths.

The placing of the decimal point in multiplication is easiest to learn when short numbers are used. The difficulties should be added step by step, and very slowly. Always keep plenty of samples before the child so that he may refer to them as models.

Percentage

The word "percent" or "per cent"—means literally "by the hundred" or "of the hundred." So five percent—5%—means five out of every hundred, or .05, or 5/100. Let us suppose, for example, that Pennsylvania produced 50% of all the steel produced in the United States. Then Pennsylvania would produce 50/100 of our steel output. Since $50/100 = 5/10 = 1/2$, Pennsylvania would make 1/2 the country's steel.

After the pupil has had a great deal of practice at learning the meaning of the common percentages such as 25%, $33\frac{1}{3}$%, 75%, $12\frac{1}{2}$%—it will be well for him to commit their fractional equivalents to memory, so that he can tell at once that $25\% = \frac{1}{4}$, or that $\frac{1}{3} = 33\frac{1}{3}\%$. He can soon learn whether, in finding a percentage, it is easier to multiply by the percent or by its fractional equivalent. In learning to find the relation in percentage that one number bears to another for instance, to answer the question, "20 is what percent of 50?"—our pupil must have a great deal of practice in simple ratio. This will later be very valuable in the study of physics and chemistry.

Short Cuts in Arithmetic

1. To multiply a number by 25 divide it by 4 and add two zeros to the right in the quotient. $80 \times 25 = 2{,}000$
2. To divide a number by 25 multiply it by 4 and point off two places in the product. $364 \div 25 = 14.56$.
3. To multiply by 10 add one zero to the right. $245 \times 10 = 2{,}450$
4. To multiply by 100, add two zeros to the right; by 1,000, three zeros to the right, etc. $245 \times 100 = 24{,}500$; $367 \times 1{,}000 = 367{,}000$.
5. To divide by 10, point off one place to the left.
6. To divide by 100, point off two places to the left, etc. $745 \div 10 = 74.5$ $745 \div 100 = 7.45$ $745 \div 1{,}000 = .745$
7. To find the square or square root of a number use the table on a later page.

Algebra

Algebra is a kind of shorthand mathematics. By it we can save time and effort, since it simplifies calculations which otherwise would be very long and cumbersome. We are able to solve problems by algebra which we could hardly solve in any other way. Here are a few of them:

The difference between the ages of the father and son is 30 years. In 8 years the father's age will be 4 times the son's age. Find the age of each now.

Jack and Tom were engaged to deliver packages for a firm. At the end of the first day Jack said: "To-day I traveled 3 miles per hour more than the number of hours I spent in traveling." Tom said, "I started to deliver two hours after you and went 14 miles farther, so I must have traveled 8 miles per hour faster than you." How many miles did each travel that day in delivering goods?

A man rowing downstream has a speed of 9 miles per hour. In rowing upstream against the current his speed is 3 miles per hour. What is the rate of the current? What would be his rate in still water?

Jim was shopping for his mother. He found that a box of strawberries and 4 pounds of sugar cost 49 cents, while at the same prices 2 boxes of strawberries and 5 pounds of sugar cost 90 cents. Find the cost of each.

Two airplane pilots compete in a flight of 7,800 miles. The ratio of the distance traveled by one plane to the distance traveled by the other is 6 to 7. What is the total distance traveled by each plane?

While algebra makes use of numbers, as arithmetic does, those numbers are practically always small. For the most part algebra expresses the facts of a problem by using letters of the alphabet to stand for numbers. In general it is a preparation for work in the sciences in high school, college, and professional schools, especially for physics, chemistry, and engineering.

We shall set down here a few rules for success in this useful and interesting branch

of mathematics. The first rules are for the student:

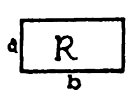
Work slowly and carefully. Never make a mistake if you can help it. It is better to solve a few problems accurately than to mess over many. Never go on into a new unit of work until you have mastered everything leading up to it.

And we also have some rules for the parent or teacher, or the elder brother or sister who is kind enough to lend a helping hand at home:

Never suggest haste to the student. Encourage him to work slowly and carefully. Try hard to keep him from making mistakes. Errors are likely to persist; they slow up progress and lead to confusion and discouragement. See that each unit of work is mastered by your pupil before he attacks a new one. In so far as is possible, have each individual learner advance at his own rate of successful progress.

Terms Used in Algebra

Algebra has its own special vocabulary. The first step in learning algebra is to learn what a "literal number" is—that is to say, what we mean when we use a letter to represent a number. It is really no more than giving a nickname to someone you know. Perhaps it is a friend you have known all your life, one whose name you will remember as long as you live, but because "Shorty" or "Red" is more convenient than Algernon or Cadwallader, your friend becomes "Shorty" or "Red" for all ordinary purposes. Or perhaps your man is a perfect stranger whom you are having to work with before you have been introduced. You will refer to him as "Sandy" for the time being, and so long as everyone understands, it won't make any difference what his real name may be. You will find that out later. As a matter of fact, in algebra *X*, *Y*, and *Z* are the nicknames we give to unknown quantities, and the whole purpose of the game is to find out what their real names may be.



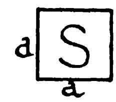
The area of the rectangle R = a times b, or ab. For in algebra when two letters are written side by side in this way we mean that the numbers they represent are multiplied, one by the other. The total area of seven rectangles exactly like R would be 7 times ab or 7ab.

What Is "A Times A"?

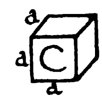
In the term "7 ab" we call 7 the "numerical coefficient" (kō′ĕ-fĭsh′ĕnt). The coefficient of 5 ax is 5; the coefficient of 3 zy is 3, and so on. What is the coefficient of xy? It is 1 understood, or 1 xy.

The area of the square is a times a, or a^2.

We read it "a square."



The volume of the cube

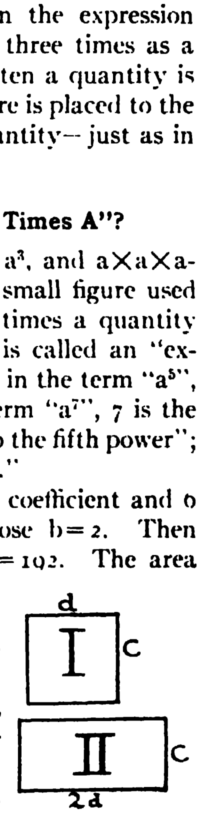


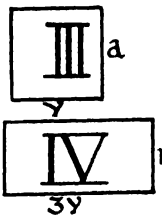
is found by saying that $c = a \times a \times a = a^3$. In the expression "$a^2$" or $a \times a$, the number represented by a—we call it the "quantity" a—is used two times as a factor. In the expression "a^3" or $a \times a \times a$, a is used three times as a factor. To indicate how often a quantity is used as a factor, a small figure is placed to the right of and above that quantity—just as in arithmetic.

What Is "A Times A Times A"?

Thus $a \times a \times a$ is written a^3, and $a \times a \times a \times a \times a$ is written a^5. The small figure used to indicate the number of times a quantity has been used as a factor is called an "exponent" (ĕks-pō′nĕnt). So, in the term "a^5", 5 is the exponent; in the term "a^7", 7 is the exponent. We read a^5, "a to the fifth power"; a^7, "a to the seventh power."

In the term $3b^6$, 3 is the coefficient and 6 the exponent. Now suppose b = 2. Then $3b^6 = 3 \times 2 \times 2 \times 2 \times 2 \times 2 \times 2 = 192$. The area of rectangle I is $c \times d$ or cd. The area of rectangle II is $c \times 2d$ or 2cd. The sum of these two areas = cd + 2cd = 3cd. The terms cd and 2cd are similar terms and so may be added because the literal quantities—or "letter quantities"—cd are alike in both.





Of rectangle III the area is ay. Of rectangle IV the area is $3ny = (n \times 3y$ or $n3y$, always written $3ny$). The sum of these two areas is $ay+3ny$. The sum can only be indicated by the use of the plus sign—for ay and 3ny are not similar terms.

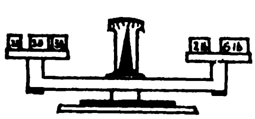
Suppose one number is three times another number. How shall we express their sum? Let x = the smaller number. Then $3x$ = the larger. Their sum is $x+3x$ or $4x$.

Paul has 4 dollars more than Carl. Then if Carl has x dollars, Paul has $x+4$ dollars. Together they have $2x+4$ dollars.

The hub of algebra is the equation. All the mathematical formulas you have ever used or will use are equations. An equation is a short way of stating that two expressions are equal. $2 \times 2 = 4$, $A = ab$, $C = \pi d$, $P = 2(a+b)$ are all equations. We can illustrate the meaning of an equation by a pair of balances. Then 6 lb. + 2 lb. = 3 lb. + 3 lb. + 2 lb., or 8 lb.

Keeping the Balance Even

Suppose we add 3 lb. to one side of the scales. Then, to keep a perfect balance, we



must add 3 lb. to the other side. Then 11 lb. = 11 lb.

Suppose we multiply the weight on one side by 5. Then, to maintain the balance, we must multiply the weight on the other side by 5. Therefore, 40 lb. = 40 lb.

Suppose we divide the weight on one side by 4. Then, in order to maintain the balance, we must divide the weight on the other side by 4. Therefore 2 lb. = 2 lb.

Some Facts about Equations

Now we can state the following facts about equations:

1. When the same number is subtracted from each side of an equation, the result is still a true equation.
2. When the same number is added to each side of an equation, the result is still a true equation.
3. When each side of an equation is multiplied by the same number, the result is still a true equation.
4. When each side of an equation is divided by the same number except zero, the result is still a true equation.

If 2 pencils cost 10 cents, one pencil costs $10 \div 2 = 5$ cents. In algebra we may say it this way: If $2a = 10$, $a = 5$. To prove this, we substitute 5 for a. Then $2a = 2 \times 5 = 10$.

How to Solve an Equation

Equations can become more and more complex. The nature of the equation to be solved will indicate what we shall do to solve it. Sometimes we shall add a certain number to each side of the equation, in order to simplify the equation; or we shall subtract a certain number from each side, multiply each side by a certain number, or divide each by a certain number. For example, in the equation $\frac{3}{4}a = 12$, it is easiest to multiply both sides by 4. Then we shall have the equation $3a = 48$. Whatever we do in solving an equation, we shall do in order to find out the value of the letter or letters in the equation.

Positive and Negative Numbers

$$-8 \quad -7 \quad -6 \quad -5 \quad -4 \quad -3 \quad -2 \quad -1 \quad 0 \quad +1 \quad +2 \quad +3 \quad +4 \quad +5 \quad +6 \quad +7 \quad +8$$

We read -3 as negative 3, -1 as negative 1.
We read $+3$ as positive 3, $+1$ as positive 1.
A boy finds 7 marbles. This we may express as $+7$.
A boy loses 5 marbles. This we may express as -5.
A man owes a debt of \$800. This we may express as $-\$800$.
A girl earns \$345. This we may express as $+\$345$.

In arithmetic, subtraction is learned before multiplication. But in algebra it is better

to learn multiplication before subtraction. Why? Because students more easily confuse positive and negative signs in subtraction than in multiplication. So subtraction is the harder.

There are just two simple rules for signs in multiplication:

1. Like signs give a positive sign.
2. Unlike signs give a negative sign.

From this it follows that:

$$-8 \text{ times } -4 = +32$$
$$+5 \text{ times } +3 = +15$$
$$+6 \text{ times } -9 = -54$$

When the plus sign is omitted a number is understood to be positive. 5 times $3=15$ is the same as $+5$ times $+3=+15$.

We can express multiplication in several different ways:

(1) 4 times $a=$
(2) $4 \times a=$
(3) $4.a=$
(4) $4(a)=$

But when there is danger of confusion we never use form (2) or (3). When, for example, we wish to state $a-b$ times $a+b$ we write $(a-b)(a+b)$; or multiply

$$\begin{array}{r} a-b \\ a+b \\ \hline \end{array}$$

If we have a form like $2a+3(a+b)+2(a-2b)-6$, we remove the parentheses by multiplying as indicated. Thus we have $2a+3a+3b+2a-4b-6$. Collecting the like terms, that is, adding like terms together, we have $7a-b-6$.

To succeed at subtraction we need first to know three simple terms: minuend (mĭn′-ū-ĕnd), subtrahend (sŭb′trȧ-hĕnd), difference:

8 minuend
5 subtrahend
3 difference

Then we need to know this one rule: To subtract in algebra, change the sign of the subtrahend—in your mind and add.

Subtract: $+6a$
$\underline{-2a}$

In our minds we think that $-2a$ is changed to $+2a$, then we add $+6a$ to $+2a$ making $+8a$.

Instead of saying, "Subtract $m-18$ from $4m+7$," we may state it as $(4m+7)-(m-18)$. When the signs are changed in the subtrahend, this will read $4m+7-m+18$. And the answer will be $3m+25$.

How to Divide in Algebra

As in arithmetic, division in algebra is the reverse of multiplication. Once the fundamental operations have been mastered thoroughly, further work in elementary algebra is relatively easy. Use of a table with squares and square roots saves much time and effort.

Some Reminders

1. We can add or subtract only like terms. Addition of other terms must merely be expressed with the proper signs.
2. We can multiply unlike terms as well as like terms.
3. When we multiply, we multiply the coefficient—as we multiply in arithmetic—and add the exponents.
4. In removing parentheses preceded by a minus sign, we change all the signs which were in the parentheses. In removing parentheses preceded by a plus sign, we make no change of signs at all.

One can now buy self-teaching books in algebra. From them a person of average intelligence can, with little or no help from a teacher, learn the elementary course in this subject.

Geometry

Geometry has a difficult sound and seems at first glance to have very little to do with our daily lives. But the truth is that its various shapes and figures lie all about us; the facts that it teaches are necessary every time a city is laid out, a building is put up, or a machine is constructed. On other pages of these books you may read of the great man who did so much to formulate this knowledge and to make its rules clear for us to-day.

Now the word "geometry" means nothing more than "land measurement." The definition will help one to guess how the science came about. It has to do with the study of shape, size, and position, and the measurement of distances, surfaces, and volumes.

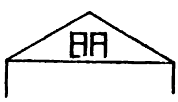
TABLE OF SQUARES AND SQUARE ROOTS

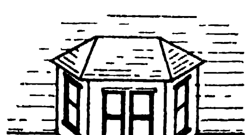
No.	Square	Square Root	No.	Square	Square Root	No.	Square	Square Root	No.	Square	Square Root
1	1	1.000	41	1 681	6.403	81	6 561	9.000	121	14 641	11.000
2	4	1.414	42	1 764	6.481	82	6 724	9.055	122	14 884	11.045
3	9	1.732	43	1 849	6.557	83	6 889	9.110	123	15 129	11.091
4	16	2.000	44	1 936	6.633	84	7 056	9.165	124	15 376	11.136
5	25	2.236	45	2 025	6.708	85	7 225	9.219	125	15 625	11.180
6	36	2.449	46	2 116	6.782	86	7 396	9.274	126	15 876	11.225
7	49	2.646	47	2 209	6.856	87	7 569	9.327	127	16 129	11.269
8	64	2.828	48	2 304	6.928	88	7 744	9.381	128	16 384	11.314
9	81	3.000	49	2 401	7.000	89	7 921	9.434	129	16 641	11.358
10	100	3.162	50	2 500	7.071	90	8 100	9.487	130	16 900	11.402
11	121	3.317	51	2 601	7.141	91	8 281	9.529	131	17 161	11.446
12	144	3.464	52	2 704	7.211	92	8 464	9.592	132	17 424	11.489
13	169	3.606	53	2 809	7.280	93	8 649	9.644	133	17 689	11.533
14	196	3.742	54	2 916	7.348	94	8 836	9.695	134	17 956	11.576
15	225	3.873	55	3 025	7.416	95	9 025	9.747	135	18 225	11.619
16	256	4.000	56	3 136	7.483	96	9 216	9.798	136	18 496	11.662
17	289	4.123	57	3 249	7.550	97	9 409	9.849	137	18 769	11.705
18	324	4.243	58	3 364	7.616	98	9 604	9.899	138	19 044	11.747
19	361	4.359	59	3 481	7.681	99	9 801	9.950	139	19 321	11.790
20	400	4.472	60	3 600	7.746	100	10 000	10.000	140	19 600	11.832
21	441	4.583	61	3 721	7.810	101	10 201	10.050	141	19 881	11.874
22	484	4.690	62	3 844	7.874	102	10 404	10 100	142	20 164	11.916
23	529	4.796	63	3 969	7.937	103	10 609	10.149	143	20 449	11.958
24	576	4.899	64	4 096	8.000	104	10 816	10.198	144	20 736	12.000
25	625	5.000	65	4 225	8.062	105	11 025	10.247	145	21 025	12.042
26	676	5.099	66	4 356	8.124	106	11 236	10 296	146	21 316	12.083
27	729	5.196	67	4 489	8.185	107	11 449	10.344	147	21 609	12.124
28	784	5.292	68	4 624	8.246	108	11 664	10.392	148	21 904	12 166
29	841	5.385	69	4 761	8.307	109	11 881	10.440	149	22 201	12.207
30	900	5.477	70	4 900	8.367	110	12 100	10.488	150	22 500	12.247
31	961	5.568	71	5 041	8.426	111	12 321	10.536	151	22 801	12.288
32	1 024	5.657	72	5 184	8.485	112	12 544	10.583	152	23 104	12.329
33	1 089	5.745	73	5 329	8.544	113	12 769	10.630	153	23 409	12.369
34	1 156	5.831	74	5 476	8.602	114	12 996	10.677	154	23 716	12.410
35	1 225	5.916	75	5 625	8.660	115	13 225	10.724	155	24 025	12.450
36	1 296	6.000	76	5 776	8.718	116	13 456	10.770	156	24 336	12.490
37	1 369	6.083	77	5 929	8.775	117	13 689	10.817	157	24 649	12.530
38	1 444	6.164	78	6 084	8.832	118	13 924	10.863	158	24 964	12.570
39	1 521	6.245	79	6 241	8.888	119	14 161	10.909	159	25 281	12.610
40	1 600	6.325	80	6 400	8.944	120	14 400	10.954	160	25 600	12.649

Measurement is necessary if the farmer is to know what land he may use. The architect must use measurements when he draws up a plan for a house. The contractor must use it when he shapes the wood and stone and glass and metal of which the house is built. The furnishing of the house requires a knowledge of shape and size and position. Even the simplest object cannot be manufactured without calling such information to our aid. The making of a map—whether of the earth or of the stars—is possible only after careful measurements have been taken. Such measurements upon the surface of the earth we know as "surveying."

It is interesting to see how many geomet-

rical shapes we can find in nature. The sun and moon of course appear to us as perfect circles. A rainbow is a curved line, and the ripples running out from a pebble dropped into a silent pool are all perfect circles. Raindrops are perfect spheres; and an orange is close to being one. If it is cut squarely in half the cut edge of the peeling around the cross section will be a circle. Have you ever spilled water on a hot stove? Those dancing globules are perfect spheres. And the same is true of drops of quicksilver that has been spilled on almost any surface. Melted lead dropped through cool air from a high sieve will turn into perfect spheres of shot.





Man too has made things after many geometrical forms. The Indian's wigwam is a fairly perfect cone. And the famous pyramids (pĭr′ȧ-mĭd) of Egypt are excellent examples of one of the geometrical solids that are called pyramids. The gable of a house is a triangle; the walls, ceiling, and floor of a room are often parallelograms (păr′ȧ-lĕl′ō-grăm) - that is, the opposite sides are parallel throughout their length.

Geometry All around Us

If you consider the whole body of a simple house, you will probably find that the part below the eaves is a rectangular solid, and the part above the eaves a triangular prism (prĭz′m). The round face of a clock and all the wheels on our vehicles are perfect circles, and so are the plates from which we eat. Cans of food, ash cans, storage tanks, silos, and smokestacks are usually cylinders (sĭl′ĭn-dẽr). And lamp shades are likely to be frustums (frŭs′tŭm) of cones or pyramids.

The rim of the clock's face is an excellent place to study the parts of a circle. At three o'clock the length of rim between the hands is a quadrant (kwŏd′rănt), or quarter circle. When it is six o'clock the rim of the clock is divided into two semicircles, or half circles. At any time of day the hands divide the circle into two arcs, for an arc is any part of a circle.

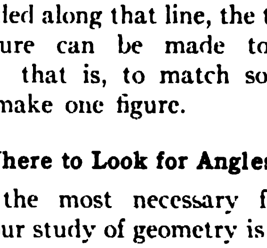
All these common notions of shape and size and position belong to what we know as intuitive (ĭn-tū′ĭ-tĭv) geometry—they are facts that we learn from everyday experience. But it is very important that we get these facts clearly in mind, for later we shall use them over and over again in studying demonstrative (dē-mŏn′strȧ-tĭv) geometry.

Some Important Terms

Before we go on with more of these fundamentals it is well to make clear a few terms that we shall use. When we speak of figures as being "equal" we mean that they have the same size. When we say they are "similar" we mean that they have the same shape they may be equal or unequal in size. When we say that they are congruent (kŏng′grōō-ĕnt) we mean that they have the same shape and size. A figure is symmetrical (sĭ-mĕt′rĭ-kăl) in regard to a line if, when the figure is folded along that line, the two halves of the figure can be made to coincide (kō′ĭn-sīd′) that is, to match so perfectly that they make one figure.

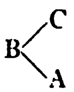
Where to Look for Angles

One of the most necessary foundation stones for our study of geometry is an understanding of angles. We see them everywhere about us at the corners of books, of pictures, of rooms, and at the intersection of streets and roads. The "right angle" is the one we know best. It is the one between the hands of the clock when they tell us that it is three o'clock. But there are other kinds of angles, for every time two straight lines meet at a point they form an angle. A map of a city's streets shows lines meeting at every imaginable angle.



The lines which form an angle are called its "sides." The point where these lines meet

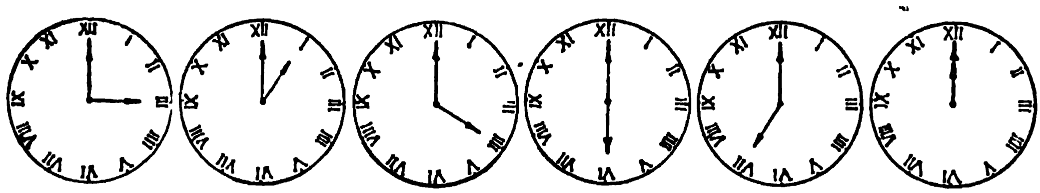
is called the vertex (vēr′tĕx) of the angle. As a rule we use any three capital letters for indicating an angle, and when we read these letters we always put the one at the vertex second.



We might speak of this angle as "angle ABC" or as "angle CBA." Sometimes an angle is indicated by a small letter inside the vertex— d and would then be read "angle d." Or it may have a single capital near the vertex O and be read "angle O." Often we substitute a picture of an angle for the word "angle." The angle just mentioned we should then write "$\angle$O."

A New Use for the Clock

Our faithful clock will serve us well in the study of angles. It is especially useful in view of the fact that an angle is scientifically defined as a "turning," and if we were to give a very learned definition of it we should describe it as "the amount of turning made by a line rotating through a plane about a fixed point." Now this is precisely what the hands of a clock are always doing, they are rotating - or turning- -through a plane -in this case they move just above the plane, or surface, formed by the face of the clock- and they turn about a fixed point, which is the pivot on which they are mounted at the center of the clock's face.



At three and at nine o'clock the hands form a "right angle." This is the angle that you have at the corners of any perfect square. When the hands form a straight line— that is, when they point in opposite directions, as they do at six o'clock—they form what is known as a "straight angle." Often—at one o'clock, for example - they form an angle that is smaller than a right angle. Such an angle we call an "acute angle" - the word "acute" means "sharp." At four o'clock the angle formed is greater than a right angle but smaller than a straight angle. We call it an "obtuse angle" —the word "obtuse" (ŏb-tūs′) means "blunt."

What Is a "Round Angle"?

At seven o'clock our hour hand has turned through an angle that is larger than a straight angle. It is a "reflex"— or "bent back"— angle. The angle at the left of the hands is of course an obtuse angle. By twelve o'clock, when the two hands are together, the hour hand has turned through a complete circle and has formed a "round angle." Acute, obtuse, and reflex angles are often called "oblique" (ŏb-lēk′) angles.

The line that is turned to make the circle is called the "radius" (rā′dĭ-ŭs) of the circle. Or, in other words, a circle's radius is always the distance between the curve line and the center. A "diameter" (dī-ăm′ē-tēr) is a line straight across the circle through the center. As you may readily see, it will be twice the length of the radius.

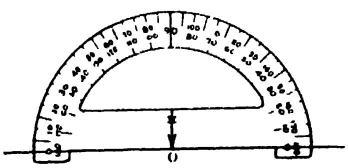
There are certain instruments that help us to draw the various geometrical figures. Everyone knows the ruler, which makes it possible to draw a straight line. Two other useful "tools" are the compass and the protractor. The compass or "pair of compasses" is useful in drawing circles or arcs, and the protractor is useful in measuring angles.

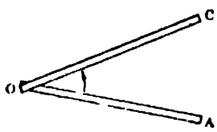
How Do We Measure an Angle?

It is sometimes hard to remember that to measure an angle does not mean that we take its area —an angle is not an inclosed space. It is, as we have already said, an "amount of turning" made by a line rotating through a plane around a fixed point. If this is borne in mind it will be much clearer why we should measure it as we do. Since our rotating line - let us think of it as a hand on a clock— describes a circle as it turns, the natural way to measure the amount of turning in an angle

is to find out how much space the angle would take up if it were placed with its vertex at the center of a circle. In order to do this we divide up a circle into parts any circle, of course, for its width across has nothing to do with the fact that it has been made by rotating a line around a point. The line may be long or short, but whatever its length, the amount of turning necessary to form a circle will always be the same.

For the purposes of measurement our circle will be divided into 360 equal parts, each one called a "degree." We indicate a degree by placing a small circle above and to the right of a numeral 90°. The number of degrees in a circle is as old as Babylon,





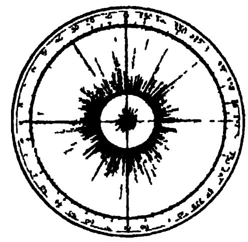
COA is really a compass. To measure ∠ COA place the compass on the protractor shown above it with points O coinciding and OA lying along the bottom of the protractor.

for the ancient men who studied the stars divided a circle into 360 degrees. We still follow their custom to-day.

Now if a circle, or complete turn that is, a round angle contains 360°, a semicircle, or straight angle, must contain half of 360°, or 180°; and a quarter circle, or quadrant that is, a right angle must contain a fourth of 360°, or 90°. And so on! It will be possible to measure an angle of any size in this way As you doubtless know, a degree is divided into sixty "minutes" and a minute into sixty "seconds."

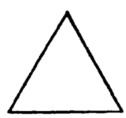
With our ruler, compasses, and protractor we can now draw circles, angles, and triangles. A triangle is a figure consisting of three straight lines intersecting in such a way as to inclose a space. If all the sides of the triangle are of equal length we say that the triangle is equilateral (ē'kwĭ-lăt'ẽ-răl), or "equal-sided." If only two sides are equal we say that it is an isosceles (ī-sŏs'ĕ-lēz) triangle. If no two sides are equal it is a scalene (skā-lēn') triangle. We have shown examples of all three kinds.

When one angle of a triangle is a right angle we have what is called a "right tri-



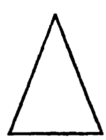
This sailor's compass shows the degrees in a circle.

angle." When one angle is an obtuse angle we have an "obtuse triangle." When all the angles are acute angles, we have an "acute triangle."

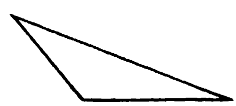


Equilateral △

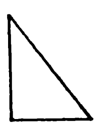
Scalene △



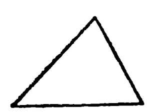
Isosceles △



Obtuse △



Right △



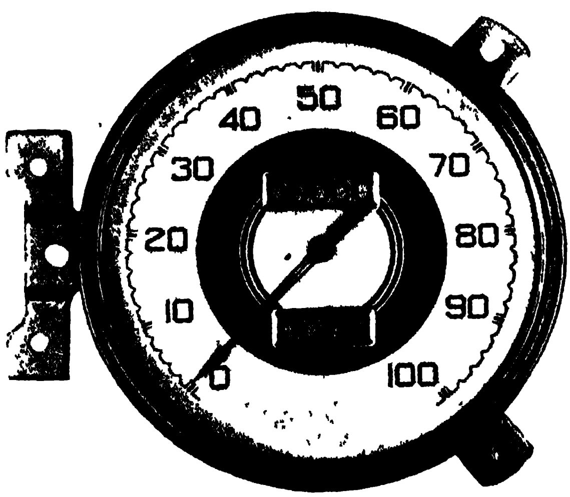
Acute △

Of course there are many other figures having straight sides. There is the rectangle, a four-sided figure in which all the angles are right angles. Then there is the pentagon (pĕn'tȧ-gŏn), with five sides; the hexagon, with six sides; the octagon, with eight sides; and the decagon (dĕk'ȧ-gŏn), with ten sides. All of them are polygons (pŏl'ĭ-gŏn)—that is, they have many sides.

Now strange as it may seem, from the information that we have given thus far the whole science of geometry may be built up, step by step. Each step rests on the one before it, and leads to the one that follows. Once you have glimpsed the inescapable logic of it and have seen the height of the towering mathematical structure that rests so firmly on so simple a foundation, geometry will seem to be one of the most beautiful things in all the universe of ideas.

We have not space here to go through all that noble structure, but we can hardly be too emphatic about the importance of the journey. This will be the student's first rigorous training in the nature of proof. It will not be enough to say that one line is perpendicular to another because he can see that it is! He must be able to show a better reason. Once he really sees what we mean by *proving* a statement, he will always thereafter hate the "sloppy thinking" so common in this world. Then, no matter how much other people may "jump at conclusions," he will aspire to make his own reasoning as sternly logical and as inescapable as the proof of a proposition in geometry. Of course this is an ideal very hard to attain. We are all amazed, when we examine our opinions, to see how few of them rest on any sound foundation.

Occasionally a student may have trouble with some particular lesson. That will probably be because he has forgotten something that went before or is not quite clear about it. There are certain basic matters that he will need to have at his finger tips. He will need to see clearly, for instance, how we prove that the sum of all the angles inside a triangle is always equal to two right angles. And there will be other necessary propositions. But once he understands the important fundamentals, nothing that follows need give him trouble.



Here is a simple geometrical figure very familiar to anyone who drives an automobile. It looks much like a clock or a sailor's compass, but of course it is a speedometer. When a car is in motion the needle is always turning back and forth through the scale that is registered around the rim of the dial, and that scale is carefully devised so that the position of the needle will show the speed of the car. Speedometers are operated on various principles, but a flexible shaft and a gear mechanism always connect the instrument either with the transmission or with one of the road wheels. The size of the road wheel has to be taken into account. The mechanism that registers distance is called an odometer (ō-dŏm'ē-tẽr). Our picture shows a speedometer that contains an odometer and a clock. The odometer finds out how far a car has gone in a given time, and of course the time is measured by the clock. Now if you divide the distance by the time, you learn the speed. This division is done by another mechanism, which controls the needle on the face of the dial.

Reading Unit No. 13

TWELVE THOUSAND STITCHES A MINUTE

Note: For basic information not found on this page, consult the general Index, Vol. 15.

For statistical and current facts, consult the Richards Year Book Index.

Interesting Facts Explained

Things to Think About

How many kinds of sewing machines are there?
Why did workmen destroy Thimmonier's sewing machines?
When did the Arabs bring the sewing needle into Europe?
How did Howe improve the needle in the sewing machine?

Picture Hunt

Related Material

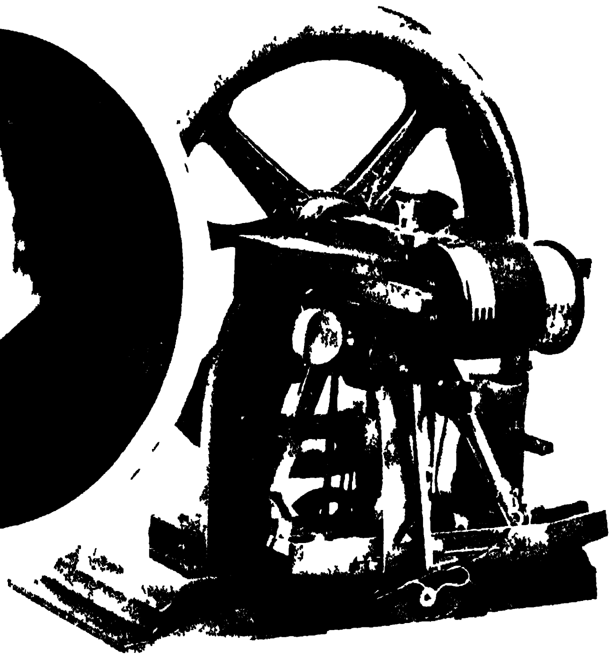
Leisure-time Activities

PROJECT NO. 1: Learn to sew a seam by machine.

PROJECT NO. 2. Find out how a sewing machine works.

Summary Statement

Until a hundred years ago, everything in the world was sewed by hand. Now machines in our big factories save us endless work and provide all the clothing we need.

This is Elias Howe, chief inventor of the sewing machine; at the right is his first model. Next time you run up a seam, think how much work he has saved us all.

Photos by National Museum and Science Museum

TWELVE THOUSAND STITCHES *a* MINUTE

Even If You Can Ply Your Little Needle Pretty Fast, You May Be Surprised to Know There Are Machines That Will Go So Much Faster

TAKE a needle and sew a seam just as fast as you can. Count the stitches. Get someone to hold a watch and say "Stop" at the end of one minute. You will know how many stitches you can take in a minute.

Then remember that in the big factories there are machines with several needles that sew twelve thousand stitches in a minute, and you will see what the sewing machine has done for the world. It will take you at least a whole day to make all those stitches; so the big machine will go about five hundred times as fast as you can. Now think of how much work is saved, and how many more clothes are made, by one invention.

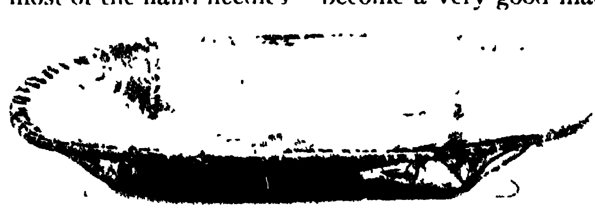
Everything in the world was sewed by hand until about a hundred years ago. Millions of people had to sit plying their needles and straining their eyes until far into the night, to make enough clothes to cover their backs. And then came one clever machine to do nearly all the work, and set them free.

It was a long time coming. Far back in the dim past, when a man used to go out and kill any animal he could find to eat, he found out that he could use the animal's fur to keep him warm. He punched a few holes in the skin and then ran a string of rawhide, also made out of the skin, through the holes. At first he must have punched the holes with a thorn or a sharp piece of bone, and run the string through with his fingers. But sooner or later he got the notion of doing both of these things at once. Then he shaped a slender piece of bone or bronze to a sharp point, and bored a hole in the end of it. He ran the string through the hole; and then he could punch and sew at the same time. He had invented the first needle

We have found needles like that in the ruins of Egypt, and of Greece and Rome. But it was still a long way to the little steel needles we all know to-day.

China Gives Us the Needle

These bright little needles seem to have come from the Chinese. In the Middle Ages the Arabs who swarmed into Europe brought these needles with them, and a little later the Germans were making them. By the time of Queen Elizabeth they could be bought in the shops of London, and just a little later the English were making them for themselves. To this day most of the hand needles come from Germany and England, though most of the machine needles are made in America.



Although the Indians had no sewing machines, they were sometimes clever with their needles of bone. This food tray is birch bark sewed together with rawhide.

It was an Englishman named Thomas Saint who seems to have had the first notion of hitching the needle to a machine. He made a good many drawings, and took out a patent for a sewing machine in 1790. But his ideas never succeeded. Then in 1830 a French tailor named Thimmonier (tē'mô'nyā') patented a rude machine that worked well enough for him to put eighty of them to work in a factory. But the workmen thought he was taking away their work, and they smashed all his machines and nearly killed him. He kept on with his invention, but he never reached success.

A Great American Inventor

Then the scene shifted to America, and most of the credit for the sewing machine lies in this land. About 1832 Walter Hunt of New York made a very good machine, with an eye-pointed needle and a shuttle to make a lock stitch. These two inventions were of great importance, but Hunt made the mistake of never taking out a patent on his work; and all the profit went to others.

Next came Elias Howe, of Massachusetts. He was born of a family of inventors. One of his uncles is said to have built the first spring bed. Another built the first truss bridge ever put up in America—the Howe Truss over the Connecticut River at Springfield. When Howe started working at his machine, he apparently had not heard of Hunt's at all.

Howe's father was a farmer, who also ran a flour mill, and in this mill the boy began to learn something about machinery when he was still very young. He was meant to be a farmer too, but he liked machinery too well. So he left the farm as soon as he could, and by the age of twenty-one he had become a very good machinist. But he had his own ways of doing things, and his employers did not always like them; and since he was often in poor health also, he was often out of work. Yet he had married very young, and he and his family were frequently in dire poverty because he was unemployed.

One day in Boston he heard his employer talking to a man who had invented a poor sort of machine for knitting. The employer said there was a fortune waiting for the man who could make a sewing machine. One night a little later, as Howe lay ill, he was watching his frail wife bent over her needle till late hours—for she had to take in sewing to get food for the family. At that moment Howe started to invent his machine.

When he had a job, he worked on his machine at night, and when he was out of work he put all his time upon it. But it took a long while. What bothered him most was the needle. He toiled a whole year before he found that a double-pointed needle with an eye in the center would not do. But finally he had a sudden idea of putting the eye at the end of a grooved needle and of having a shuttle to carry a second thread to lock the stitch.

When a Dream Came True

The story goes that it all came to him in a dream. In his worry over his invention

and over the poverty of his wife and children, he is said to have dreamed that he had been brought before a great heathen king. The king ordered him to finish his machine or give up his life. Then the time passed and the machine was not ready. The warriors came to his cell, to lead him to his death. In the head of every spear they carried was a hole like an eye!

Howe awoke, and flew to his machine. The problem of the needle was solved, and the machine was soon ready to run. That was in 1844. Of course this story may all be one more invention, but it *is* the kind of dream a man might have in such conditions.

But Howe still had a world of trouble ahead of him. He challenged some women to a sewing race, they with needles and he with his machine. Of course he won, but all he had for his pains was the hatred of the women, who thought he would take their work away. Then he had no money to put his machine on the market. For a while an old school friend came to his aid, advancing $500 for a half interest in the machine. But the friend grew tired of it, and no one else would take an interest in it. For a while Howe had to work as a railway engineer to get bread for the family. Then his health broke down again, and he had to give up that. But at least he had taken out a patent that was going to mean a fortune.

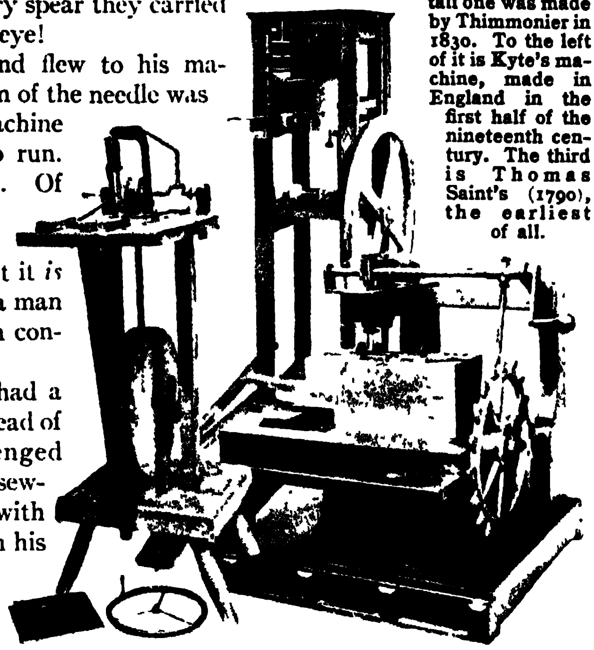


Photo by Science Museum London

How different from our swift and beautiful sewing machines of to-day! These are three early types. The tall one was made by Thimmonier in 1830. To the left of it is Kyte's machine, made in England in the first half of the nineteenth century. The third is Thomas Saint's (1790), the earliest of all.

The Bitter Struggles of an Inventor

Now there seemed to be a chance in England. A man in London named William Thomas bought the rights to it for $1,250 and offered Howe $15 a week to come over and work with the machine in his shop. So Howe moved with his family to England. But he soon found he could not get along with Thomas. He had to borrow enough money to send his wife and children back to America, and then work his own way back as a cook on a boat. He landed in 1849, without even enough money to reach the bedside of his ill wife. When he had borrowed the money, he arrived only to see her die.

But things had been happening while Howe had been abroad. Machines like his own had got into the market, using his patents. He now borrowed enough money to fight for his rights in the courts. There was a long struggle, but in the end he won. And before he died, in 1867, the men who were using his patents had paid him about $2 000,000.

Since that day, the sewing machine has seen all sorts of improvements, though the basic principle has remained the same. Among the main improvers have been Allen B. Wilson, William O. Grover, James A. E. Gibbs, and Isaac M. Singer. To-day millions of machines are turned out every year.

There are a great many kinds of sewing machines. A single American company makes about three thousand different kinds. Some of them are turned by hand, some by foot, some by electricity. There is a tiny machine, weighing 2½ pounds, on which to learn how to sew, and there is a big one, weighing 2½ tons, for sewing great machine belts as much as an inch and a half thick. There are machines for sewing on buttons and for cutting and sewing buttonholes. Some work with a single thread and make a chain stitch; some with two threads and make a double chain or a lock stitch.

Reading Unit No. 14

THE MAGIC OF THE CAMERA

Note: For basic information not found on this page, consult the general Index, Vol. 15.

For statistical and current facts, consult the Richards Year Book Index.

Interesting Facts Explained

How men learned to make the sun draw pictures, 10 446-47

What the first cameras were like, 10-447

How Daguerre discovered that the vapor of mercury would "develop" pictures, 10-448

How the calotype made modern photography possible, 10-448

Why we stand on our heads in a camera, 10-449

Why it is important to have a good camera lens, 10-449

Why the true copy of what the camera sees is called a "negative," 10-451

How films are developed, 10-450-52

Things to Think About

Why was Daguerre able to make one copy only of each picture he took?

Why do we see the world upside down in a camera?

How is a photograph made?

How did Niepce and Daguerre make the sun "draw" pictures on plates covered with chemicals?

Picture Hunt

What were the first cameras like? 10 447

How many "negatives" and "positives" can we have of a given photograph? 10-450-51

Related Material

Why do we see images upside down? 2 296-98

Why do astronomers use cameras? 1 188, 190

How are motion pictures taken? 10-503-12

How can electric current be made to carry light? 10-124

How fast does light travel? 1-179, 417, 428

How does light help plants to grow? 2 43, 50, 194, 223

Practical Applications

What special kinds of work can the camera do? 10-452

By what process are pictures of rare books taken? 10 452

Summary Statement

The camera is another sort of memory we have made for ourselves; it keeps a clear record of all sorts of things that we may want to see again or that we cannot see firsthand.

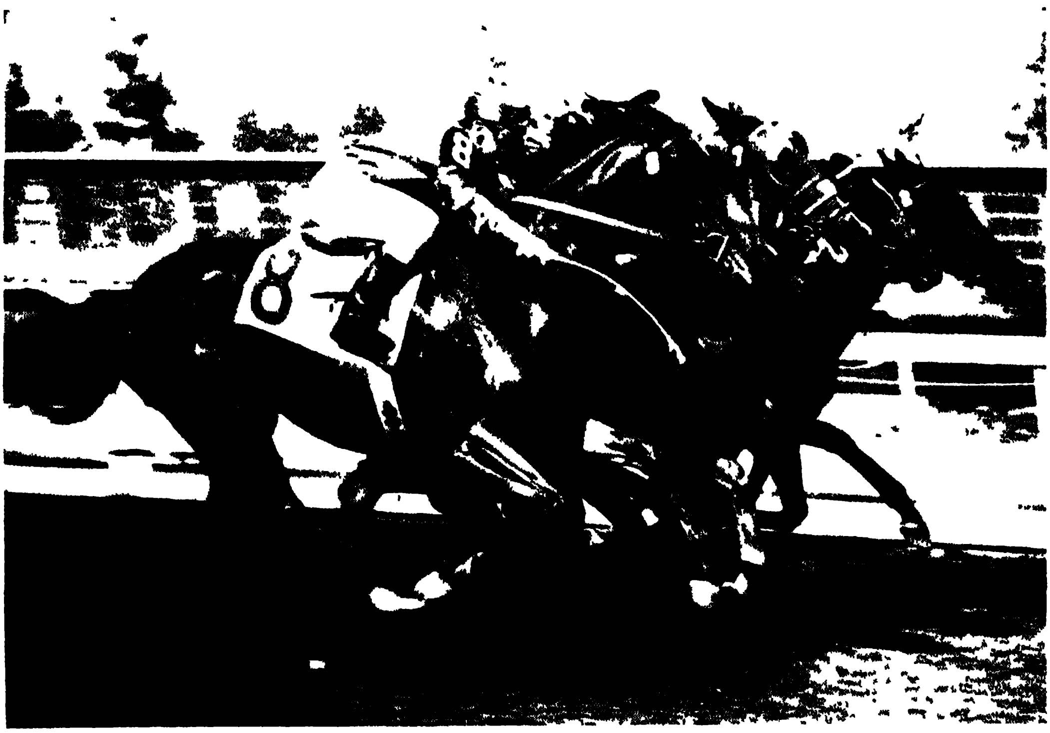


Photo courtesy Staff Photographer Hal Jensen, Los Angeles Examiner

These horses are running at about thirty miles an hour To do that, their legs are working at sixty miles an hour The camera which "froze" their motion was faster than the human eye but even then, it was slow Modern electronic equipment has been made to take pictures at one one-hundred millionths of a second!

The MAGIC *of the* CAMERA

How We Have Learned to Make the Sun Draw Pictures for Us—Millions in a Minute If We Want Them

WE ALL know how the sun changes the colors of things. It takes the color out of curtains and wall paper, and it puts color into leaves—for a plant that grows in a cellar will never be green.

If you ever want to write your name on an apple, or on a pumpkin or watermelon, just cut out the letters of your name from a piece of stiff paper and paste them on the apple about the time it is starting to get red, or on the pumpkin or watermelon about the time it is getting ripe. Take off the paper about ten days later and you will find your name written by the sun in white.

Now the story of photography—or "light writing"—is just the story of the many ways we have found to make the sun draw pictures for us by changing the colors of things that we put in the light It is hard to say who did this first As usual, a good many men began trying it about the same time, and thousands of them have been working ever since perfecting what the first ones started.

Just about two hundred years ago a German named Johann Schultze (shōōl'tse) made the sun copy on a piece of chalk some words that he had cut out in a piece of paper. Of course he never dreamed of taking a picture, and little did he think a time would ever come when millions of pictures would be taken every day. But he knew that certain chemicals change color very quickly in the sunlight, and in particular that silver nitrate (nī'trāt) turns from white to black almost at once. So he put some silver nitrate

on his chalk and placed the paper over it with the words cut out. When he took off the paper, there were his words copied in black on the white chalk.

Where the Camera Came From

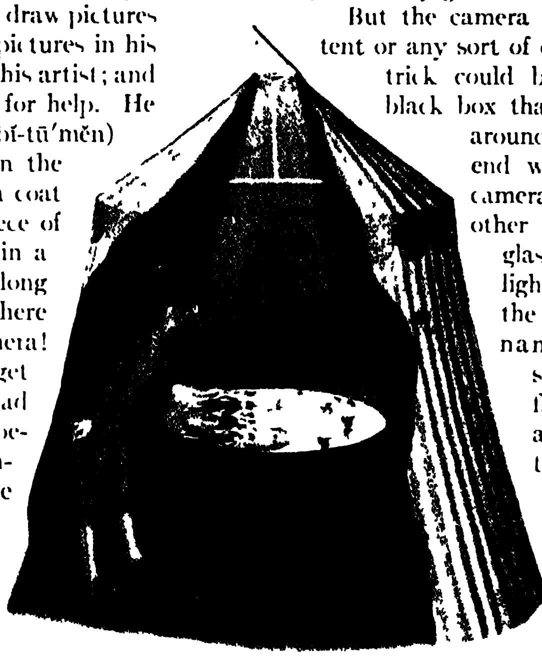
Then a good many other people did similar things. And just a century later a clever Frenchman named Niepce (nyĕps) thought he could make the sun draw pictures for him. He needed pictures in his work, but he had lost his artist; and he turned to the sun for help. He knew that bitumen (bĭ-tū'mĕn) would change color in the sunlight. So he put a coat of bitumen over a piece of silver, and placed it in a camera, after eight long hours in the sunlight there was a picture in his camera!

But where could he get a camera if no one had ever taken a picture before? Ah, that is another story. There were plenty of cameras long before pictures were ever taken. So while our clever Frenchman is waiting all day for his picture to appear, let us go back and see where his camera came from.

Centuries ago a showman would occasionally set up a strange little tent on high ground near a town or city. Inside, it was all dark, but there was a table in the center covered with white paper. People used to pay to come in and look down at the table. What they saw there was a picture of everything that was going on outside—the whole landscape, all in colors, with the people walking about and the trees blowing in the wind.

The First Camera Was a Tent

This tent was a camera obscura (kăm'ĕr-ȧ ŏb-skū'rȧ); the two words are Italian and simply mean a "dark room." There was a little hole in the tent, and a lens to collect the rays of light that came through it. Then there was a mirror on top of the tent, above the table. The rays went up to the mirror, and were thrown back down on the table to make the picture. The trick seems to have been known in ancient days, though it was not until some four hundred years ago that any great use was made of it.



This is what the first "cameras" were like. For you see the word comes from an Italian phrase meaning "a dark room." In cameras like the one above, which one had to pay to enter, a hole at the top, with a lens to gather the light rays and a mirror to reflect them, made it possible to see on a table beneath the hole everything that was going on outside the tent.

But the camera did not have to be a tent or any sort of dark room. The same trick could be done with a little black box that anyone could carry around and look into. At one end was a lens, as in our cameras to-day, and at the other was a piece of white glass to catch the rays of light that came through the lens. An Englishman named Robert Boyle seems to have made the first camera of this kind about 1670. For a century or so afterward some of the ladies who liked to draw used to carry little cameras around the country and to sketch the pictures that appeared in them.

So a hundred years ago Niepce had a camera all ready to take the first photograph. All he had to do was to take out the white glass and put in his bitumen plate. Then the light did the rest—in eight hours. The bitumen hardened where the light struck it. When the plate came out, the dark, soft part of the bitumen washed away, and there was the picture—faint enough, to be sure, but fixed so that it would not fade.

An Accident Gave Us Photography

But how many of us will wait eight hours to take a picture? And how many things will stand still as long as that to have their pictures taken?

So there was still a long way to go. And

the next great step was taken after Louis Daguerre (dä'gâr') joined Niepce as a partner. Daguerre had been a painter, and he now wanted to see if he could make the sun draw good pictures for him. For years he tried one chemical after another to find out what the sun would do the best work on, and at last, about 1839, he hit upon silver iodide (ī'ô-dīd). A plate covered with this would show a faint image from the light.

And then came one of the lucky accidents that occur so often to assist inventors. Daguerre had exposed a plate but had found no picture on it; so he put it away for the night in a cupboard where there happened to be a cup of mercury. In the morning a picture had come out on the plate—and so Daguerre discovered that the vapor of mercury would "develop" pictures!

At once he started bathing his pictures in the vapor from a cup of heated mercury. They all came out clearly; and he learned how to keep them from fading by giving them another bath in salt water. Those were the first good photographs, and after their French inventor they are called daguerreotypes (dȧ-gĕr'ô-tīp). People were soon flocking to have their pictures taken.

Sometimes the pictures were taken on a plate of tin, and so were called tintypes. Of course there could be only a single copy of each picture, for the original plate was the picture itself. So they were still different from our modern photographs.

As you read these books you will be struck by the number of times accident has stepped in to help an earnest inventor. Here is Louis Daguerre in the act of finding that Fate has helped him discover a process for photography. For he has left an exposed sensitive plate all night in a cupboard in which there happened to be a cup of mercury, and now, in the morning, he finds that the picture on his plate has come into view—"developed" by vapor from the mercury.

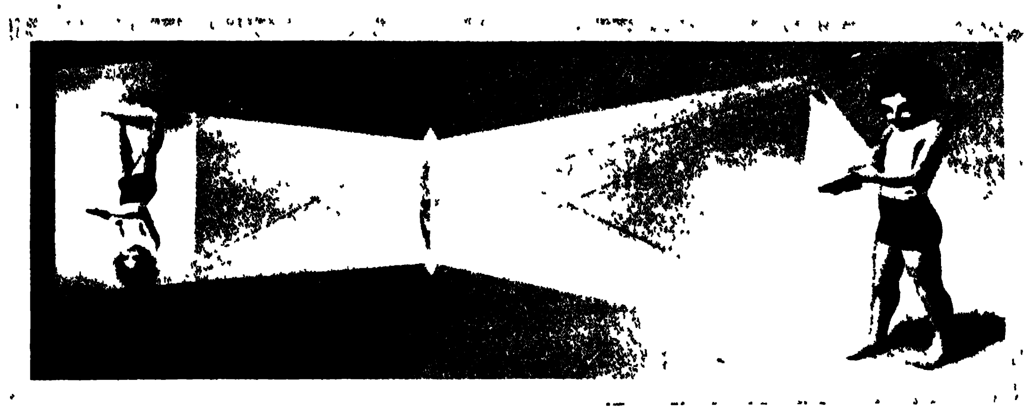
A Picture in a Millionth of a Second

Clearly the next step was to take a picture on some kind of plate from which many copies could be printed. Such a plate was very soon invented by an Englishman named Fox Talbot. It was made out of paper coated with the same silver iodide; and when the paper was moistened, the picture on it could be copied any number of times. This kind of picture is known as the calotype (kăl'ô-tīp), and with it we may say that modern photography begins. All that has been done since has only brought these first inventions to the perfection that we see to-day.

The paper plates were followed by the glass plates made by Scott Archer in 1851, and these in turn, twenty years later, by the gelatin film we use to-day. Of course there have been hundreds of other improvements. And step by step the time required to make a picture has grown less and less as the plates have been made more and more sensitive to light. A hundred years ago Niepce needed eight hours to take a single picture, and now we can take a picture in a millionth of a second which is at the rate of two hundred eighty-eight billion in eight hours! What would the good Niepce have thought if he had dreamed that pictures could be taken of a baseball whirling and curving from the pitcher to the batter, or even of a bullet whizzing through the air?

How Light Rays Are Bent

The rays of light always go straight. When they strike an object that reflects them, they bounce off it in lines as straight as those in which they came. It is true that when they pass from one kind of medium to another, as from air to glass or water, they are bent at the point where they enter



You have perhaps often heard that glass bends the rays of light as they pass through it. Because it does, we can place a glass lens in the eye of a camera so that it will bend all the rays of light that reach it just enough to throw a small picture of what the camera sees against a sensitive film behind the lens. The diagram above shows how it all works. Follow the paths of the rays from the child's head and feet and see where they go when they reach the lens. That will show you why the picture on the film is always reversed from right to left and is upside down. This happens in our eyes, too, which are really cameras.

the second medium; but after the one bend they keep on going as straight as before.

We Stand on Our Heads in a Camera

Now when light comes in at the little hole in the front of a camera and spreads out inside to make a picture on the plate at the rear, it is all turned upside down. And we can easily see why. Suppose a man is standing in front of the camera to have his picture taken. The rays of light from his head will come down to the hole in the camera, and the rays from his feet will rise up to it. They will all pass through the little hole together, and will keep right on in the same straight lines inside, to spread out over the plate at the rear. So when they reach the plate the rays from the man's head are at the bottom and those from his feet at the top; and the whole man is upside down in the picture.

We See the World Upside Down

All this happens whether there is any lens in the hole or not—it happens every time the light goes through a tiny hole. In fact, it happens in our own eyes, for the pupils are very much like the opening in the camera; we always see the world upside down, though we hardly can believe it because we always turn it right side up again so easily in our minds.

So a lens is not absolutely necessary in a camera, for we could take a picture through a pinhole if we had to do so. But we need plenty of light to take a rapid picture, and a pinhole lets in very little. What the lens does is to let in a great deal more and still send every ray of it through one point smaller than a pinhole. For a lens is just a rounded piece of glass that bulges outward in the front of the camera. Because it is larger than a pinhole it lets in more rays of light, but because it is rounded it bends the rays until they all pass through a given point and then spread out again to cover the plate in the back. You can see just how all this happens in the illustrations.

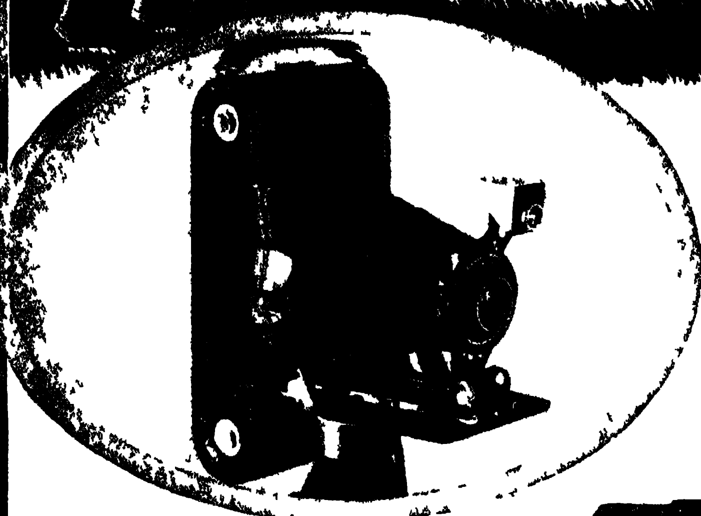
The Part the Lens Plays

That is why it is so important to have a good lens. A poor one may not send the rays exactly in the right lines, and then it will be sure to blur the picture. To make a really good lens is a fine art, and the picture it will take is marvelously clear.

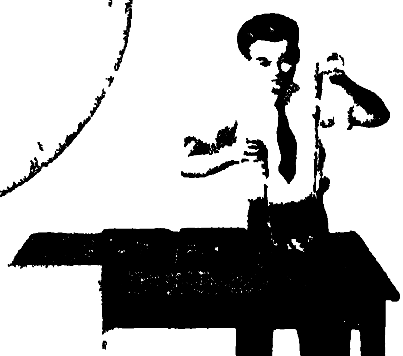
But though there must be plenty of light, it must not last too long. With most of our cameras now the light is let in only for an instant. And for this purpose we have a metal shutter, covering the lens, which can open and close so fast that we can hardly see it move.

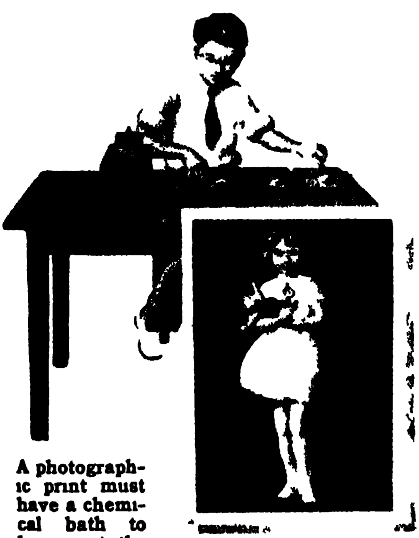
The modern film that catches the picture is a strip of celluloid coated with gelatin that has been treated with bromide (brō'mīd)

She is having her picture taken. That is to say, a little shutter is being opened to let light rays reflected from every part of her figure pass through the glass lens that you see in the front of the camera shown in the oval The shutter is just in front of the lens, and is often operated by a bulb on a long rubber tube Part of the collapsible bellows of the camera has been removed so that you may see her inverted image cast on the film at the back of the camera The film is wound into a roll at the end of the camera, and will hold many pictures



Below, our boy is treating his strip of film to a chemical bath to bring out the pictures on it.





A photographic print must have a chemical bath to bring out the picture, and one to "set" the tones.

A picture on a film has black for white and white for black, that is, it is a "negative," like the one at the right When paper sensitive to light, like the sheet above, is placed under it, the light rays reach the paper through the white parts of the negative and produce a chemical change in the paper. But the dark spots on the negative protect the paper from light.

of silver. The strip is hidden from the light in a roll of red or black paper. It is unrolled in the camera as we take our pictures, and rolled up snugly again when we are through, before we take it out.

How a Photograph Is Made

There is no sort of picture to be seen on the film when it comes out. It looks just as it did when it went in. But it holds an image all the same, which only needs to be developed.

Until it is developed we must keep it in the dark, for another touch of daylight would ruin it. In a photographer's "dark room" which is really lighted with a red or orange lamp, because a red or orange light will not hurt the picture—we can see nothing on the film except the yellow glaze of gelatin with bromide of silver in it. When the light came through the lens upon the film, it merely loosened up this chemical more or less—more where its rays were brighter and less where they were darker. Now of course the rays from a man's white collar would be much brighter than those from his dark coat; and in the same way everything about him and around him would send lighter or darker rays according to its own shade. At every point the chemical is loosened up exactly in accord with the brightness of the ray that struck it at that point. You cannot see that it is loose—but wait!

The upper picture shows the negative of the photograph below. You will see that they are the same, except that black and white are reversed. We never have more than one negative of a given photograph, but from it any number of "positive" prints may be made.

Photos by Eastman Kodak Co

As we dip the film in our developing solution, the loose chemical is washed away and the black metallic silver begins to show beneath. Where it was very loose the film grows very dark, and where it was not so loose the film is lighter. The whole film is now black and white, with every shade between, just according as the rays of light have struck it. But that is just according as the things in front of the camera were light or dark. So the film has taken a true copy of the things in front of the camera.

Now we must give the film a bath in a fixing solution of hyposulphite (hī′pō-sŭl′fīt) of soda. This will wash away all of the chemical that remains on the darker parts. And then we may take our film into the light without fear that it will ever change again.

It is a true copy, but in one way it is just the contrary of what the camera saw. All that was bright in front of the camera is dark on the film, and all that was dark is bright. That is why we call this copy a "negative." For it is just the opposite of what it copied.

So it is not the final picture yet. To make the final picture we lay the negative over a piece of printing paper which also has bromide of silver on it, and put them out in the light. The paper takes a copy of the negative, but this time with the colors as they should be. This final picture is called a "positive."

How the Camera Records Our History

Most of us are too lazy, or think we are too busy, to develop our own films. We send them off to a photographer. But we can miss a lot of fun in this way, and we

never have a chance to learn the art of the dark room. For to make a picture turn out well is a real art.

The camera does all sorts of work for us. For making certain kinds of records it can have no equal. Just suppose we had pictures of Julius Caesar and his army, of David and Goliath, and of all the famous men and things of old! With today's cameras people can keep all the pictures they may want of the great men and the great things in their history. And just as they will travel far back into the past to see the men of old, so they will sit quietly at home and see the great sights all over the world in their own day. That we can do now, for the camera will bring them all to our fireside.

A Camera for Every Need

The camera explains a host of things that are often very hard to put into words. Think how much the photographs in this book have told you! Think of the pictures of hats and shoes and motor cars and hundreds of other things that are sent out by the million every day to people who may want to buy.

To do all sorts of things we have made all sorts of cameras. If we want to find out what is in some rare and priceless old book or manuscript in Europe or Asia, we can have pictures of its pages taken by a photostat (fō'tō-stăt); and if a lot of other people would like to see it, we can print the pictures in a new book, which will be just like the old one. In some places the men who come to read the gas and electric meters simply take a picture of them with a factograph (făk'tō-grȧf)—a camera that flashes its own light to take the picture. For a picture of a distant mountain or of anything else far away, we can use a telephoto (tĕl'ē-fō'tō) camera, which has a lens like a telescope. With this a man can sit in the grandstand at a ball game and take a picture that will show whether the runner was safe or out by an inch. In order to keep records of all sorts in small space we can photograph them on microfilm—16 or 35 millimeters wide. During World War II the Germans sent their spies full-page messages on films the size of a period on this page.

There are cameras for taking pictures way down in oil wells, or far beneath the sea, or inside the human body. There are cameras that go up in airplanes to snap photographs of vast forests and wildernesses, and so help in making maps of all the country. In Canada thousands of square miles of unknown land have been mapped in this way from the sky. Such cameras are very busy when there is a war. They sail out over the enemy's lines and get pictures of all he is doing. There is even a camera that shows an aviator how to shoot. The aviator simply aims the camera at another airplane, and pulls a trigger; and the camera shows him where the shot would have gone if he had been shooting a machine gun. And there are cameras that do remarkable work in surveying.

The Sharpest Eye in the World

There are hundreds of other things that cameras do and hundreds of other cameras to do them—from the cheap little toys that will go into a waistcoat pocket to the magnificent machines for photographing stars billions of miles out of our sight, or for taking pictures of things under the microscope that are thousands of times too small to see. With a camera and a telescope we can find a million stars where we can see only one with our own eye. With camera and microscope we can make a picture of many a thing so tiny that a million of them in a pile would be too small to see. And with camera and an X-ray machine we can see the bones in our hands or a flaw in a piece of steel.

One of the most exciting of all the recent improvements in photography has been the perfecting of color film. For a good many years we have had colored moving pictures. And by 1935 it was possible to take pictures that faithfully reproduced what the eye saw and then to print them in color from the film. The process was of great value for aërial photography during the war and will be of great use to science in countless ways. So in the sciences, as in the rest of life, the camera gives us a record of many things that we should never see without it, or should find hard to remember. It is an eye with an automatic memory attached.

The STORY *of the* COMPASS

Reading Unit No. 15

EVERY SHIP MUST HAVE AN EYE

Note: For basic information not found on this page, consult the general Index, Vol. 15.

For statistical and current facts, consult the Richards Year Book Index.

Interesting Facts Explained

Why mariners of old would not go out on the deep sea, 10–454
When the compass came into use, 10 455
The compass Columbus used, 10–455
How a ship's compass is made, 10–455-56
How iron on a ship affects the compass, 10 456
The North Pole and the magnetic pole, 10 456
When Sperry invented a non-magnetic compass, 10–457

Things to Think About

Why is the gyrocompass more useful to ships than the magnetic compass?
What risks did mariners have to run when they had no compass?
Why must mariners know mathematics when they use the magnetic compass?
What use is now made of the gyrocompass?

Related Material

What is the story of Columbus' life? 13 447-55
When is a radio compass especially useful to a ship? 10 121
What did the ancient Chinese use as compasses? 1 485
What metals will magnets attract? 1 486
What is, in a sense, the ancestor of the radio and television? 1–486
How did Faraday make use of Oersted's work with magnets? 1-504-6
What is the use of the magnet in the telephone? .–520

Practical Applications

What use is made of the gyrocompass in sea and air navigation? 10-457
How does the compass show ships where to go? 10-455

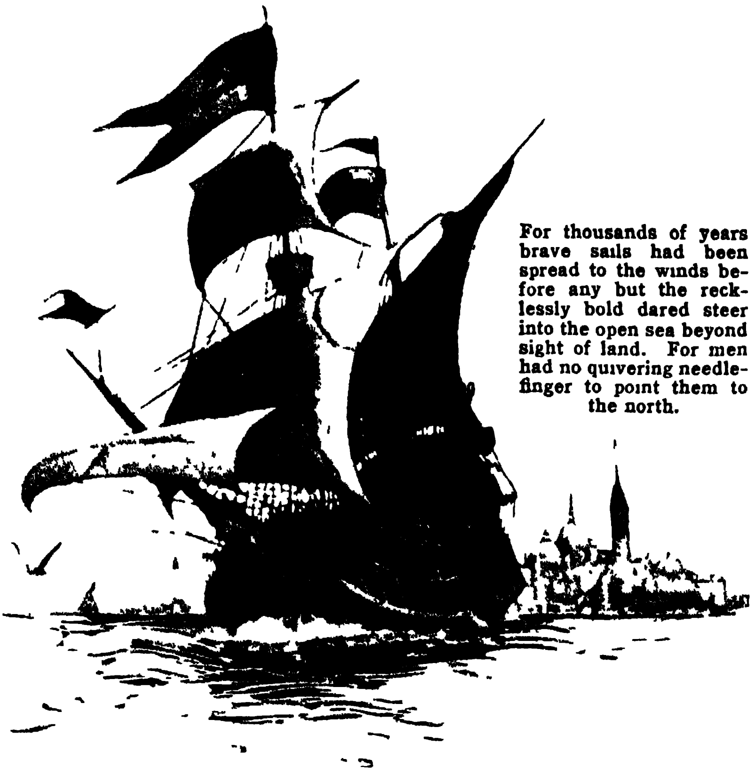
Leisure-time Activities

PROJECT NO. 1: Make a magnetic compass, 10–455

PROJECT NO. 2: Find out what a gyroscope can do, 1-291

Summary Statement

When the compass came into use, it guided mariners all over the wide seas, and it remains today the eye of many a ship, though the gyrocompass has replaced it on the larger ones.



For thousands of years brave sails had been spread to the winds before any but the recklessly bold dared steer into the open sea beyond sight of land. For men had no quivering needle-finger to point them to the north.

EVERY SHIP MUST HAVE *an* EYE

And That Eye Is a Little Needle Which for Some Reason Always Points to the North

IF YOU ever get lost in a vast forest you will have the worst time you ever had in your life. Of course you will try to walk out of it, and if you can only keep on going in a straight line you will get out sooner or later—unless you starve on the way. The trouble is that you will find it just about impossible to keep on in a straight line. You will find you are just going around in circles, and forever coming back to the place where you started.

If the sun or stars are shining you may keep in a fairly straight line by finding out the south and keeping your face to it. But if the clouds are thick, you will find it hard to tell south from north. Then you probably will have to find a stream and keep going down it. Somewhere it will turn into a river, and the river will have towns on it—and yet how a stream does wind around!

But now suppose you were lost at sea. It would be ten times worse. No hills to mark the way, no stream to follow—nothing but flat, hungry water all around you! One direction would look exactly like every other, and you would not have the least notion which way to turn your boat unless unless you had a compass. But if you only had a little compass, and could hold out, you could get to land.

Now that is why the mariners of old would never dare go into the deep sea. They had good boats, and they were brave and cunning sailors, but they had no little compass, and no way to tell where they were going. To be sure, they could often find their way by the sun or by the North Star—if the weather kept clear. But if it was cloudy or foggy, they might as well be blind. So they nearly always had to keep in sight of land. And

that, of course, was very bad, because they had to go so much farther when they skirted a meandering coast line, and because there are so many rocks and shoals around a coast. Yet it was the best they could do. They could never venture far from shore, and never dream of crossing an ocean like the Atlantic.

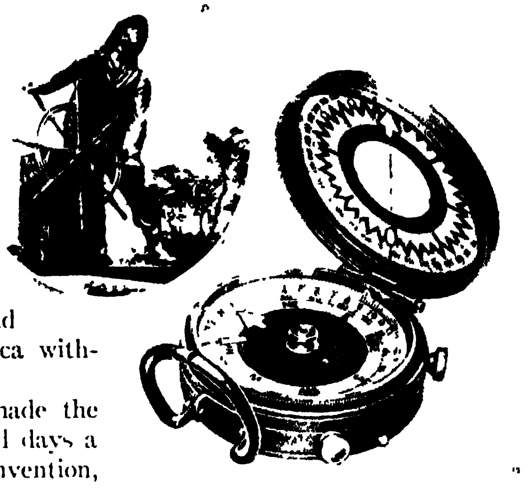
But then came the little compass, and soon they could go anywhere. Wherever they might be they could not get lost, for they always knew where the north was. And it may well be that they would never have found America without that little compass.

Nobody knows who made the first compass. In the old days a man did not patent an invention, and so leave a famous name behind him; and the invention came only very slowly into use. About the most we know is that for a long time after the year 1000 the bold sailors of Venice and other cities were still traveling just as the Greeks and Romans did hugging the coasts and sometimes letting loose a bird to see which way he would fly to get to land. But by about 1300 the compass was beginning to come into use. And a good while before the time of Columbus, it was the guide of the sailors, such as those Prince Henry the Navigator was sending down the African coast on their great voyages of discovery. It was soon to guide such men all over the wide seas, and it remains to-day the eye of every ship in the world. The proudest of our ocean grayhounds would be blind without its little needle to show them where to go.

How to Make a Compass

You can make a pretty good compass for yourself if you want to. All you have to do is to rub a needle on a piece of lodestone, or on a little horseshoe magnet, run it through a bit of cork, and then float it in a little bowl of water. In an instant it will be pointing to the north. Or you can hang it by a thread, or set it on top of a light pivot, and it will do the same thing. It will always point north and south, and you can figure all the other directions.

We have no positive proof as to why the needle does that. We just say that the whole earth is a big magnet, and let it go at that; for though we know a great deal about magnetism, we do not know what causes it, any more than we know what causes gravitation. Long ago we knew that a lodestone would act in this peculiar way, and that a piece of steel rubbed on it would do the same thing. But it was a long time before anybody thought of using the piece of steel to tell a ship which way to go, and even yet we cannot say why the bit of steel does it.



Photos by Taylor Instrument Co

Here is the helmsman, with his clear eyes and steady hand, ready for any wind or weather. And here is a simple type of the magnetic compass, his friend and guide.

How a Ship's Compass Is Made

Of course the kind of compass you would make would not do for a ship. The water in your bowl would all spill out as the ship tossed on the waves, and the needle hanging on your thread would swing around wildly. The ship's compass is a highly perfected thing, and very delicately balanced--for it must take us all the way across the ocean and get us precisely to the point where we want to go. The ship's needle is a far better one than you could make, and indeed there are several needles, to make everything surer. The needles are fastened to a compass card, with all the points of the compass marked on it, and the whole thing is mounted on a very delicate pivot, so that it may turn very freely. Then it is shut up in a tight little box, and the box itself is mounted on

Until quite lately we believed that the earth's magnetic pole, toward which the compass points, was a single point, which seemed to shift about over an area lying just north of the mainland of Canada Now we know that the magnetic pole which does not by any means coincide with the North Pole is really a large magnetic area which has three centers of magnetic strength One of these centers is at the northern tip of Boothia Peninsula Another is on Prince of Wales Island And the third and northernmost is on Bathurst Island

some ingenious supports, called gimbals, which keep it perfectly level no matter how much the boat pitches and tosses and rolls about There were compasses like that two centuries before Columbus, though of course there have been many delicate improvements since.

How Iron Affects a Compass

Though the principle of the magnetic compass is always the same— that of your little needle in your bowl of water the compass has to be made with very great care if it is going to steer a ship We all know that a piece of iron near a magnetic needle will pull the needle around from the true north more or less, according to the size of the iron and to its nearness to the needle Now boats are made of iron, or steel, and even when they are built of wood, they have nails and other bits of iron in them So the iron in the boat is always twisting the needle more or less, and the greatest care must be used in building the boat to prevent as much of this as possible, and then we must make due allowance for any pull on the needle that cannot be avoided So the makers and the users of the compass must be very skillful men It still takes good figuring to sail straight to a given point three thousand miles away over the pathless waves

Where Is the Magnetic Pole?

Then there is another thing that is even more puzzling We said the needle always pointed straight north, and so it does But it does not point at the North Pole For its own good reasons, it points at the magnetic pole, which is quite a different thing You can see this for yourself if you will take a little compass, or even your own needle, out

Photo by Grace Line

This is the array of instruments that the navigators of a modern ocean liner use in guiding their ship. In the "wheelhouse," which is on the "bridge" in the forward part of the ship, men are constantly at work directing the course of the vessel. Their most valuable aid is the gyrocompass, which is located below decks and which relays the ship's "heading" to the officers on watch by means of "gyro-repeaters."

some night and look where it is pointing. It will not be pointing at the North Star at all, but quite a bit to one side of the North Star where the magnetic pole is. Now just how much it will point away from the North Star will depend on where you are whether in New York or California, on the Atlantic or on the Pacific. In some places it will point to one side of the star, and in some places to the other side. And more curious still, the magnetic north is always changing just a little bit, and in any one year the compass will not be pointing exactly where it pointed a year ago, or ten years ago. So to find out the true north will also depend on just when you happen to be looking for it.

Anyone can see that all these things must make it very hard to handle a magnetic compass as precisely as we must in sailing over the ocean. We have to know a good deal more of mathematics than most people ever learn if we are going to do it—though of course the mathematicians help us with elaborate charts to make it easier.

For all these reasons, we wanted a compass that would not be magnetic, and so would not be forever varying. And finally an American inventor, Elmer A. Sperry, gave us such a compass in 1911. It is the gyrocompass (jī'rō), and is a very complicated device, though its principle is that of any gyroscope (jī'rô-skōp). It has nothing to do with magnetism, and it never varies or asks for any correction. This compass was first used in warships and in airplanes, but is now employed in most of the big boats of the world. In storm or fog, by night or day, it guides us across the deep as surely as if there were a signpost at every half-mile of the way. It is always used in submarines, in which the compass is entirely inclosed in iron; for under those conditions a magnetic compass would hardly work at all, and the submarine would be quite lost.

The STORY *of* TIME KEEPING

Reading Unit
No. 16

HOW WE LEARNED TO TELL THE TIME

Note: For basic information not found on this page, consult the general Index, Vol. 15.

For statistical and current facts, consult the Richards Year Book Index.

Interesting Facts Explained

When stones were used to tell the time, 10 460

When we first hear of a sundial, 10 460

When speeches were timed by water clocks, 10 461

The advantages of the hourglass, 10–461-62

Counting time with burning candles, 10 462

When the word "clock" meant a "bell," 10 464

How an Italian boy discovered the pendulum, 10 464-66

How time is kept at sea, 10 469-71

Where to-day becomes yesterday, 10 473

Things to Think About

Why are our clocks set to agree with Greenwich time?

How does the sundial tell the time?

What were the chief disadvantages of the different ways of telling time before the invention of the clock?

How does the pendulum help the clock to keep accurate time?

Related Material

What kind of clocks did the early colonists have? 12 195

How does the Naval Observatory regulate thousands of clocks in the United States? 10–99

What kinds of clocks do astronomers use? 1–186

How did time come to be an important feature in all music? 12–215

How is time kept on board ship? 10 300

What is the law of the pendulum? 1 292, 13 396-97

What regulates a watch? 1 292

Why must a telescope be adjusted if a given star is to be kept in sight? 1 186

Leisure-time Activities

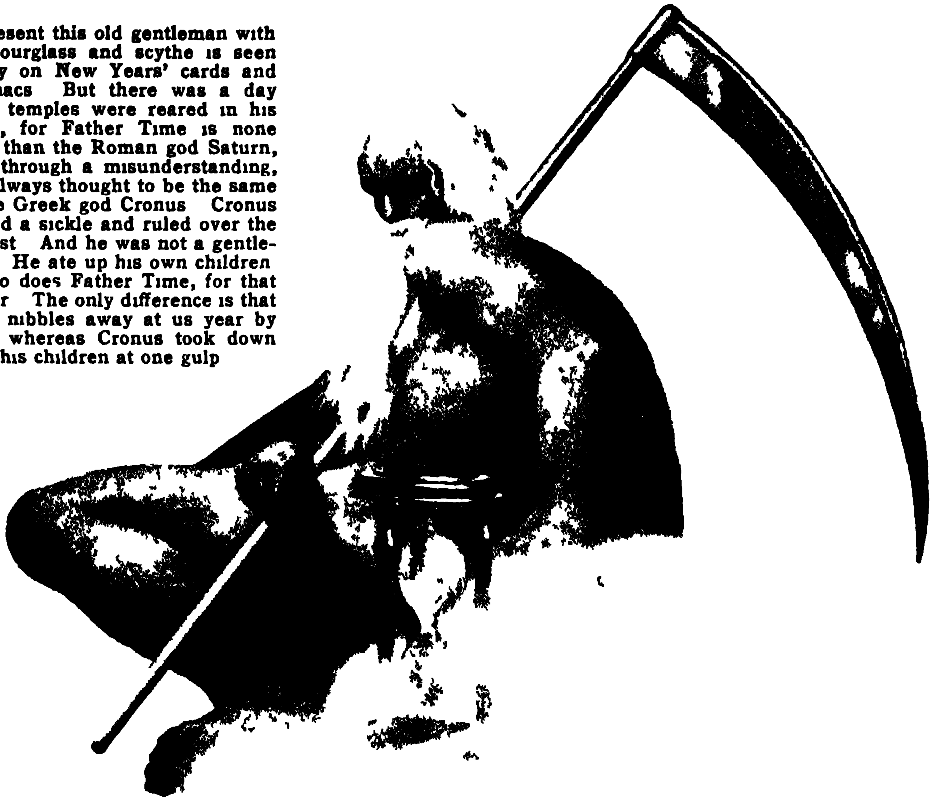
PROJECT NO 1: Make a water clock, 10–462

PROJECT NO. 2: Make a candle clock, 10 462

Summary Statement

As civilization advances time becomes more and more precious, but we have learned how to make clocks and watches that keep such accurate time that we know when to start trains or boats and when to keep engagements. Otherwise, our lives would go to pieces.

At present this old gentleman with the hourglass and scythe is seen chiefly on New Years' cards and almanacs But there was a day when temples were reared in his honor, for Father Time is none other than the Roman god Saturn, who, through a misunderstanding, was always thought to be the same as the Greek god Cronus Cronus carried a sickle and ruled over the harvest And he was not a gentleman He ate up his own children But so does Father Time, for that matter The only difference is that Time nibbles away at us year by year, whereas Cronus took down his children at one gulp



HOW WE LEARNED *to* TELL *the* TIME

Long before We Ever Had Clocks and Watches We Used to Keep the Time with Sand and Water and Candles, and Many Other Things

JUST for a minute suppose we try to think of a world without any clocks or watches, or even any sundial What would things be like? Nobody would know what time it was Nobody would know when to go to school or to work or to church the people would all be straggling along at different times No one could be sure of keeping any engagement Nobody would know when to start a boat or a train In fact, the trains would all be running into one another, because they would all be starting at the wrong time No one would even know when to eat, and a lot of us would miss our dinners! It would be a sorry sort of world

But this very world of ours was once just like that Of course it did not make so much difference then Nobody cared what time it was There were no schools or churches to go to and no trains to start And as for eating a man just ate when he got hungry—or rather, whenever he could find something to eat Nobody ever had to be "on time" There wasn't any time

So when the first man went away from his cave, neither he nor anybody else knew when he would be back He would just

come when he came, and they could expect him when they saw him. That was about all he could do about it.

But after a while, of course, he wanted to let them know about when he would be back, and in the long run he found out a way of telling them. Day after day he had noticed that the shadow of a certain rock or bush beside his cave got to about the same place at the same time every afternoon. So when he went away he set a stone down at a certain point on the ground. He would try to get back when the shadow reached that point.

Now this man was a genius for his early day. He had begun the first rude sundial. For he had found out a way to make the sun tell him the time. And we have never found anything since that will tell it better. All our clocks and watches are just machines to mark off the time that the sun tells us.

Then this man, or probably some other one, thought of another thing. If one stone in a certain place would mark the time when the sun reached it every day, then a whole set of stones, placed at certain proper distances apart, would divide up the whole day into fairly equal periods. He would know about what time it was when the shadow came to any particular stone. The first stone might mean about what we call six-o'clock in the morning, the second seven, the third eight, and so on. Then the man might stick up a sharp-pointed pole to cast a better shadow than the rock or bush; and the first sundial would be complete.

Photo by National Museum

He must have looked a great deal like this the genius who first drew a curve to mark the traveling shadow of some rock or tree, and then divided it into convenient lengths. That was the world's first sundial—a clock that could never run down.

Why We Gave Up Sun Time

How long ago it was made we do not know. Probably it was pretty old; but the first time we ever hear of a sundial is in the Book of Isaiah, XXXVIII, 8, and this comes from about 700 B.C.

Of course for a long time the sundial was far from perfect. It was of no use at night or on a cloudy day, and it was of very little use at sea, on a dancing deck. More than that, the sun never rises and sets at the same place or time any two days together. So if the shadow reached a certain stone at nine o'clock one day, it would be a little earlier or later the next day; and after a few months it would be seriously out of schedule.

By about 300 B.C., at least, a way had been invented to correct this. A man named Berossus (bĕ-rŏs'ŭs) in Babylon, a priest of the heathen god Baal of whom we hear so much in the Bible, made a hollow hemisphere, like a bowl, with a tiny ball above it to cast a shadow. The shadow of the ball traveled across the curved surface of the bowl once a day; and by dividing its path into twelve sections and then drawing some ingenious curves on the face of the bowl, one could divide every day into twelve equal parts, or "hours."

But then there was another trouble. The days of the year are not of equal length. In the winter the sun may be up for only ten hours, while in the summer it may be up for fourteen. Now if the shadow of the sun has only a brief time to travel through the twelve sections, it will have to hurry, and the "hours" will be shorter; while if it has a long time it will creep more slowly, and the "hours" will be longer. So every day would have twelve hours of sunlight, but the hours would be longer in summer than in winter. And that was always a trouble with the

"hemicycle of Berossus," as the sundial of that worthy man was called.

Telling Time with Water

Yet his sundial was so good that it came down through many centuries in Greece and Rome. Sometimes it was made fairly small, but sometimes it was big enough to fill a whole courtyard. Sometimes it was a dark cavern with one little beam of sunlight coming through a hole in the top.

But the curved dial was an awkward thing. It was hard to read unless it was large, and then it would be hard to make. So the world mostly went back to flat sundials, with the pointer directed due north, and found out ways of making them pretty accurate. Indeed, people made very elaborate and very beautiful sundials all through the days of Greece and Rome, and all through the Middle Ages, down to two or three hundred years ago, when clocks and watches began to grow common. After that, the sundial was used mainly for an ornament in gardens, as it still is from time to time.

Photo by Deutschen Museum

At the left is the clever water clock of Ctesibius of Alexandria. As water ran out of the container it turned a set of water wheels, and these operated machinery that caused a little figure with a pointer to rise gradually and so to indicate the numbers on an index. Athens is thought to have had a clock of this kind in its famous Tower of the Winds, with the cistern for it in one of the turrets.
At the right is one of the familiar sundials. Its shadow at noon points directly north; and as the sun travels down the sky, the shadow travels too, through all the hours of afternoon. With the setting of the sun, the dial goes to sleep for the night; but it wakes precisely at sunrise, and proceeds to mark the morning hours that lead up to noon.

Long before that, however, men had found out other ways of keeping time—ways to count the time at night, on cloudy days, or on the sea. One of these was the famous water clock, or "clepsydra" (klĕp′sĭ-drȧ). The word comes from the Greek and really means the "water thief."

How a Water Clock Works

At first it was simply an earthenware vessel with a tiny hole in the bottom. When this was full of water, the water would drip slowly away, and one could measure the time it took for all the water to leak out. Then he would know that this amount of time would always pass between the first drop and the last drop.

As long as the clepsydra was thick earthenware one could hardly tell how much of the water had run out at any moment, or how much time was gone. So the thing was soon made out of glass, to remedy that trouble. But then the water ran much faster when it was full than when it was nearly empty; and the next thing was to arrange to keep it always full, and measure the water that had run out, into another bowl beneath. But at best it was an uncertain timepiece. It was too likely to get clogged, and then the orator might go on forever!

For in Rome men used to time their speeches in the law courts by the clepsydra. The poet Martial has a story about a tiresome speaker who kept wetting his lips with a sip of water and who finally said it might relieve him and his hearers if he drank out of the clepsydra!

The clepsydra lent itself to the jeweler's art, and was often very beautiful and very costly. It could be a gift for kings. And sometimes it could be very ingenious. Indeed, a certain Ctesibius (tē-sĭb′ĭ-ŭs) of Alexandria, about 140 B.C., made a clepsydra with a system of cogs that caused a pointer to indicate the hours of the day. This was the nearest thing to a clock in ancient days. But the great fault of the clepsydra is that it did not tell the hours - it only told how much time had gone by since it started. Even so it stayed in use for a long while—in France and Italy until around the year 1500—though it sometimes froze in winter!

This last trouble never happened with the hourglass. For the hourglass used sand, or in rare cases mercury, instead of water; and

fine sand will trickle through a little hole at a very even rate. The hourglass was a fat tube pinched in at the waist to leave only a tiny hole. When the sand had run out of the top into the bottom, the glass could be turned upside down to let it run back, or to begin another hour. Of course the glass did not always measure an hour; sometimes it counted only half an hour, and it could be made to count any period from a minute upward.

We do not know how old the hourglass is, but we have found a picture of one in Rome from about three centuries before Christ. The glasses were still in use till clocks and watches came. Preachers used to keep an hourglass to time their sermons, and to this day there is one in use in the English House of Commons. It runs for only two minutes. When there is going to be a vote, the speaker starts the sand running, and all sorts of bells are rung to tell the members they must be there to vote in two minutes, before the sand is out.

There have been still other ways of counting time, and almost anybody could invent one if he tried. Sometimes it has been counted with a burning candle. For a good candle, well protected from the wind, will burn at a very even rate, and it can easily be marked off into sections an hour long.

But all of these devices had their faults, though at their best they were astonishingly accurate. None of them would do to run a train by, and none of them except the sundial would tell what time it was—whether six o'clock or twelve o'clock—but only how long it was since they had been started. The sundial would tell the hour, at least approximately, but only when the sun was shining. So

Photo by National Museum

Suppose you found yourself in a land that had neither clocks nor watches. Which one of the timepieces above would you choose? All of them have been used by mankind at some time or other. The flame creeping at steady pace between the equal intervals in a knotted string, water dripping slowly out of a glass vessel with a scale on its side, a candle burning quietly through section after section of its length, a moving sunbeam striking through a hole in a ring and pointing to a number—all these were accurate enough for the needs of the men who used them. But as civilization advances, time becomes more and more precious. The burning candle that King Alfred always used was replaced by the lamp clock in the center of the picture. In it the steady flame on a wick in the little troughlike affair at one side burned up the oil in the glass and made it fall steadily along the scale marked on the strip of metal against the container. But best of all was the hourglass. The flow of its fine sand was not affected by weather, and went on at the same speed whether the glass was full or nearly empty.

Photo by Alinari

It was this great Italian who made our modern clocks and watches possible. Here Galileo is shown in the cathedral at Pisa on that windy Sunday when the swinging lamps taught him the secret of the pendulum.

Clever gardeners like to make these floral clocks, in which a mechanism hidden inside the mound drives a pair of hands over the top of a round flowerbed planted to represent the face of a clock.

something better than all this was needed, though nothing better came until toward the end of the Middle Ages

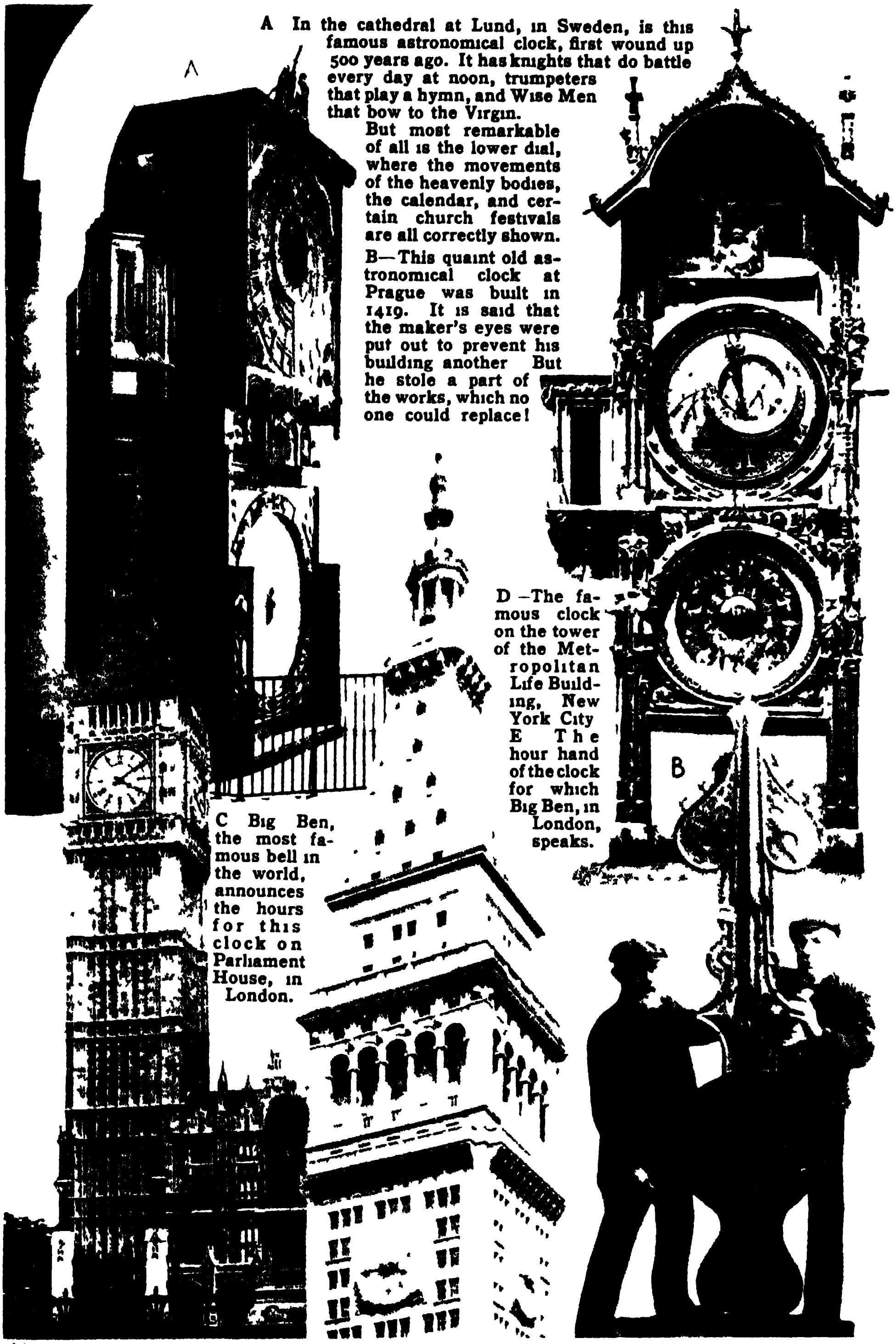
Clocks without Faces

By that time there were a great many big churches and cathedrals. Then some one invented a machine to ring a bell and call all the people to church at the same time. It was not exactly a clock at first; it had no hands or face, and it did not tell the time. It only rang a bell. But it was the father of all clocks, and the very word "clock" in the beginning meant a "bell." It worked with a heavy weight which turned some wheels; and when the wheels reached a certain position, they made the bell ring. Sometimes they made an iron figure of a man, or some similar thing, step out of the machine and strike the bell with a hammer. Such figures were called "Jacks of the clock."

No one knows just who made the first clocks or just when But by the year 1300 they were beginning to be like our modern big clocks, with a face and a hand to tell the time. By 1379 there came what has been called the parent of all our modern timepieces. It was then that the king of France called on Henry de Vick to build a clock for the royal palace in Paris. And the clock he made is still standing, though the royal palace has long since turned into the Palace of Justice. It was driven by a weight of five hundred pounds, and it still had only one hand, but it followed the same basic principles of clocks down to our day. For about two centuries after it there was no great change in clocks.

A Boy Discovers the Pendulum

And then came the pendulum. In 1581 an Italian boy who was just beginning to study medicine was sitting in the great, draughty cathedral of Pisa watching the hanging lamps as they swung back and forth in the breeze. Now they would be swinging just a little way; then a gust would strike them and they would swing a wide sweep. And the boy began to notice something. Since he was the first person in all the world to notice it, we need not be surprised to



A In the cathedral at Lund, in Sweden, is this famous astronomical clock, first wound up 500 years ago. It has knights that do battle every day at noon, trumpeters that play a hymn, and Wise Men that bow to the Virgin. But most remarkable of all is the lower dial, where the movements of the heavenly bodies, the calendar, and certain church festivals are all correctly shown.

B—This quaint old astronomical clock at Prague was built in 1419. It is said that the maker's eyes were put out to prevent his building another But he stole a part of the works, which no one could replace!

C Big Ben, the most famous bell in the world, announces the hours for this clock on Parliament House, in London.

D –The famous clock on the tower of the Metropolitan Life Building, New York City

E The hour hand of the clock for which Big Ben, in London, speaks.

know that he was a great genius—no other than the famous Galileo (găl'ĭ-lē'ō).

He noticed that however far the lamp swung, it always took the same length of time to come back. If it went a little way, it traveled slowly, and if it made a big swing it went fast; but always it took exactly the same time to get through. And that was an important discovery in science, for since then the pendulum, or swinging weight, has taught us a great deal.

Galileo did not at once put a pendulum into a clock. He only showed the doctors how they could count pulses with a pendulum. But others soon saw what it would do for the clock, and in 1665 the great Dutch scientist, Christian Huygens (hī'gĕnz), made a far more accurate pendulum clock than the world had ever seen before. He needed it to time the movements of the stars, and ever since then the world has had accurate clocks to time anything at all. The minute hand now appeared—it had hardly been needed before, because the clocks might well be many minutes out of time anyhow—and finally the second hand came.

Most people even now do not know how a

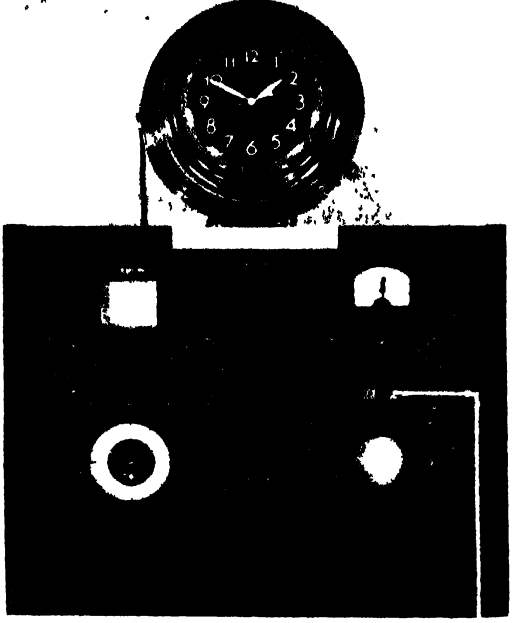


Photo courtesy National Bureau of Standards

This atomic clock, representing one of the peacetime uses of atomic energy, is the most accurate timepiece ever invented. Its measurement of time is based on the movement of atoms in ammonia molecules.

clock works. Of course there are many kinds, and they are often very complicated; but the basic principles are always the same.

First, there must be some power to make the wheels go round. That is supplied by a heavy weight that is always pulling down. Then there must be something to keep the wheels from going too fast or too slow—or to make them always keep the same steady pace. That is the pendulum, with its never-varying swings back and forth. And finally there must be the network of cogged wheels, all working together at different speeds but all keeping time with the pendulum as they turn the hour hand very slowly, the minute hand faster, and the second hand faster still. For each hand must go sixty times faster than the one behind it.

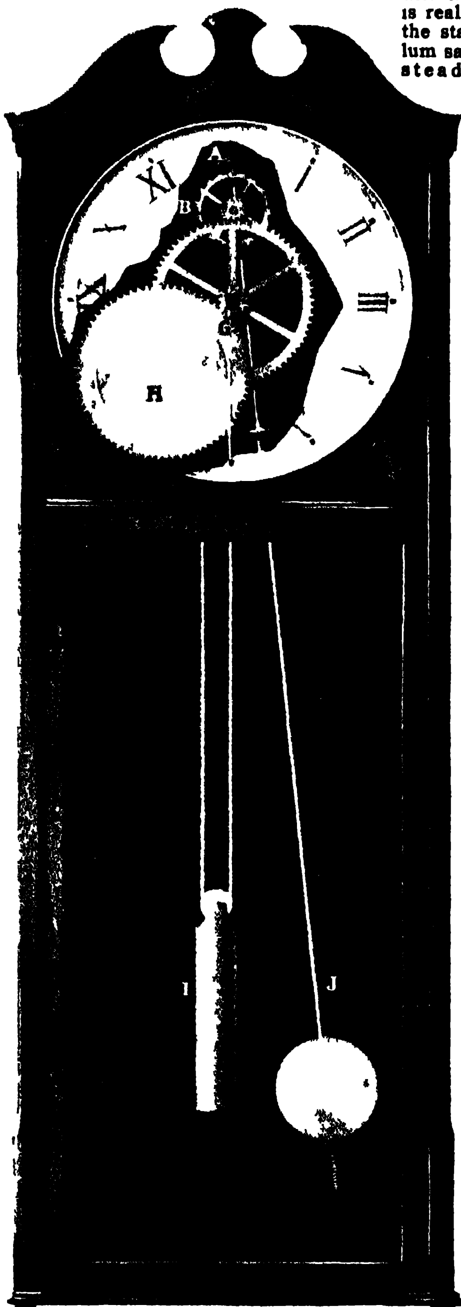
How the Pendulum Works

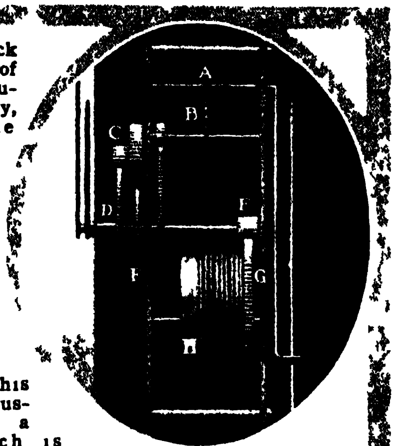
Now the weight pulls on a big wheel and makes it turn slowly around, and through the system of cogs, this big wheel makes all the smaller wheels, of various sizes, turn at their various proper speeds, while the pendulum swings back and forth to keep the big wheel going at exactly the right pace. For at the top, the pendulum is attached to a lever catch which works in and out of a set of notches, or "teeth," controlling the big wheel. Every time the pendulum swings back, the catch lets the wheel slip a tooth, and then it holds the wheel still till the pendulum swings back again.

And since the pendulum always swings back in the same time, the big wheel always slips one tooth in the same time, and all the other wheels behave accordingly. But what keeps the pendulum going? Why doesn't it "die down"? Why, every time it comes to the end of a swing, it gets a little kick from the lever catch, and so it keeps right on. But suppose the whole clock goes too fast, or too slow? Then we just make the pendulum a little longer or shorter—there is a screw to do that—until we get it exactly right. For the shorter a pendulum, the briefer its swing, and the longer the slower. In this way we "regulate" the clock.

And that is all there is, except detail, to the ingenious machine. In any big old clock you can see the weight and pendulum for

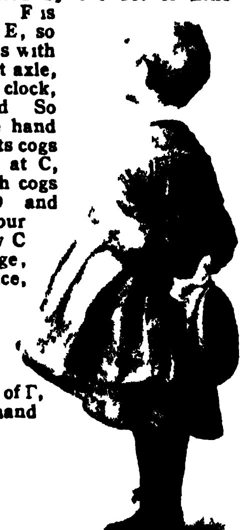
The clock's tick-tock is really the voice of the staid old pendulum saying, "Steady, steady," to the wheels





The most accurate clocks work with a pendulum, and have a weight, I, to turn the wheels This weight is suspended by a cord which is wound around the barrel-shaped wheel H The pull of the weight turns the wheel, on which are a set of cogs, at G, fitting into cogs on the little wheel E So as H turns, E turns too as is shown at the left Now E is fastened to the axle of a much larger wheel which has to turn as E turns This larger wheel is really in front of E, though in the left hand picture we have had to show it behind E Cogs on the edge of the larger E-wheel fit into the cogs on a small wheel, and turn it round To this small wheel is attached a larger cogged wheel B, which has to turn when the little wheel is turned But right here a finger is put in for the first time to stop all this chain of action started by the weight pulling on H For the little swinging rod at A, which is attached to the pendulum J as you may see from the side view in the oval now catches the wheel B by a cog and stops it until the pendulum swings back Thus a brake is applied to prevent the weight from making the clock go too fast

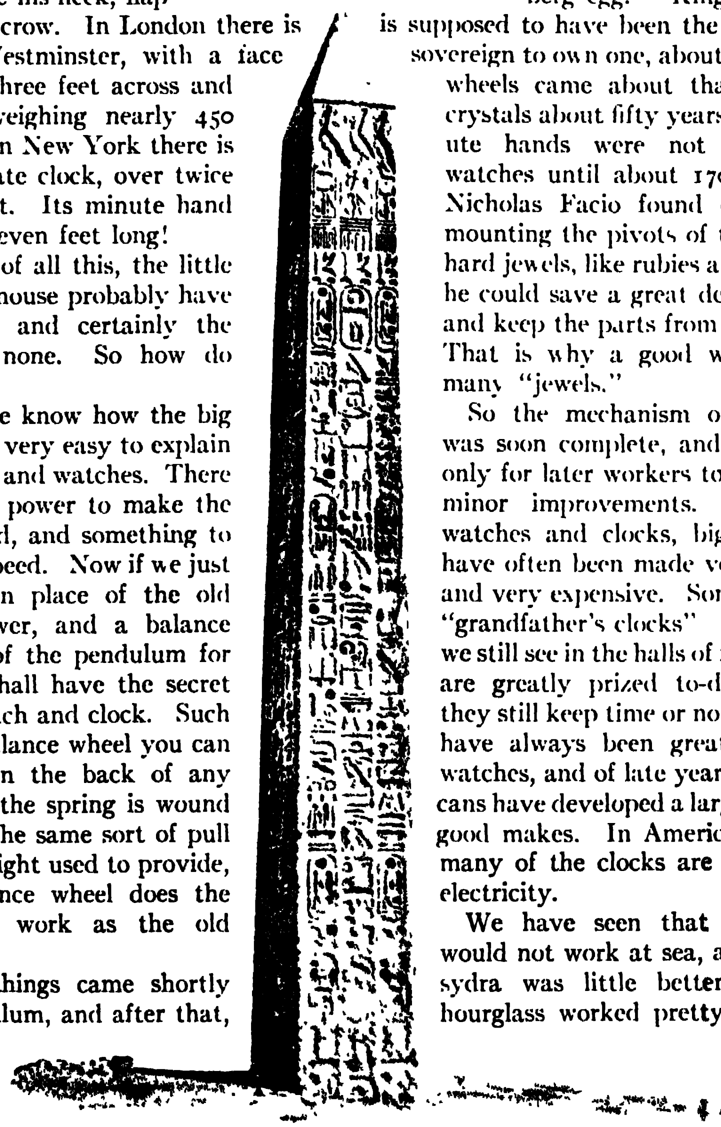
The hands are controlled by the set of little wheels at F, D, and C F is on the same axle with E, so as E goes round, F turns with it Now the end of that axle, out at the front of the clock, carries the minute hand So as F turns, the minute hand turns But as F turns, its cogs turn the double wheel at C, which is also fitted with cogs which turn the wheel D and to the wheel D the hour hand is attached Now C is small, and D is large, so to turn D around once, C will have to revolve a good many times In this way D, with its slow hour hand, is made to go round with one-twelfth of the speed of F, with its swift minute hand



HOW WE WIND A CLOCK

When the pull of the weight I has quite unwound the cord at H in the oval above the clock is said to be "run down" Now it must be "wound up", that is, the cord must once again be wound around the wheel H, and the weight thus raised

yourself, and watch them work. And some day you may see some of the great clocks of the world that do all sorts of remarkable things. There is one at Strasbourg in France, first built in 1352, which not only tells the hours, but shows the day of the week and of the month, gives the position of the sun and moon and planets, and even predicts eclipses. Every day at noon it shows a procession of the figures of the Twelve Apostles and makes a huge cock on top of a tower ruffle his neck, flap his wings, and crow. In London there is Big Ben of Westminster, with a face about twenty-three feet across and a pendulum weighing nearly 450 pounds. And in New York there is the great Colgate clock, over twice as large as that. Its minute hand is over thirty-seven feet long!



This great pointed shaft told time for the pharaohs in Egypt sixteen hundred years before the birth of Christ. It now stands in Central Park, New York City; and it has a twin in London. They are known as "Cleopatra's Needles," but the king who set up these two great obelisks as pointers for his sundials lived long before Cleopatra's day.

Photo by Metropolitan Museum of Art

But in spite of all this, the little clocks in your house probably have no pendulums, and certainly the watches have none. So how do they run?

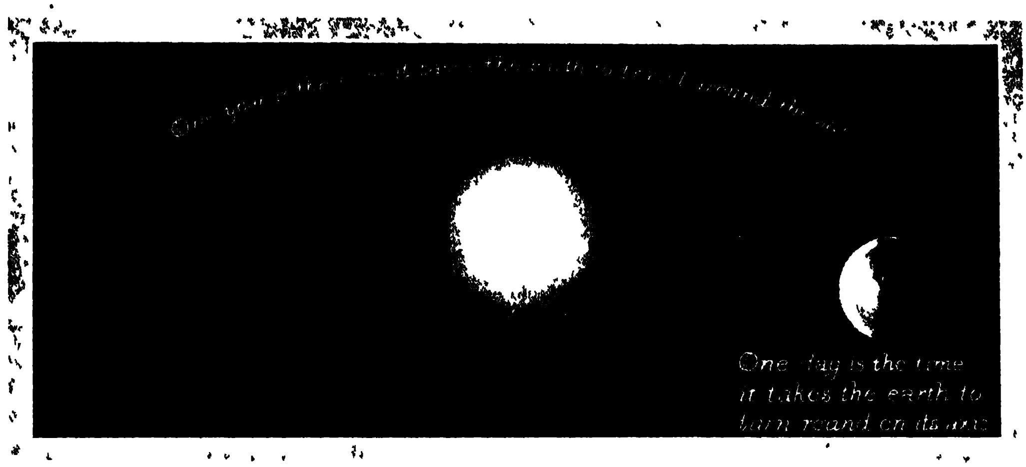
Well, once we know how the big clocks run, it is very easy to explain the little clocks and watches. There must still be a power to make the wheels go round, and something to regulate their speed. Now if we just put a spring in place of the old weight for power, and a balance wheel instead of the pendulum for regulator, we shall have the secret of the little watch and clock. Such a spring and balance wheel you can see if you open the back of any watch. When the spring is wound up it supplies the same sort of pull that the old weight used to provide, while the balance wheel does the same kind of work as the old pendulum.

These two things came shortly after the pendulum, and after that, clocks could be small, and watches could be made. The old clock, named for a bell, had at first been something to listen to, but the new watch, as its name shows, was something to look at. The first spring is said to have been made of a pig's bristle.

The names of Jacob Zech (zĕk) of Prague and of Gruet (grü'ĕ') in Switzerland are intimately connected with the early watches. And an early kind of watch made at Nuremberg in Germany was so fat and round that it was called the "Nuremberg egg." King Edward VI is supposed to have been the first English sovereign to own one, about 1550. Brass wheels came about that time, and crystals about fifty years later. Minute hands were not common in watches until about 1700. In 1704 Nicholas Facio found out that by mounting the pivots of the watch on hard jewels, like rubies and sapphires, he could save a great deal of friction and keep the parts from wearing out. That is why a good watch has so many "jewels."

So the mechanism of the watch was soon complete, and it remained only for later workers to make many minor improvements. Of course watches and clocks, big and small, have often been made very beautiful and very expensive. Some of the old "grandfather's clocks" the tall ones we still see in the halls of fine houses are greatly prized to-day, whether they still keep time or not. The Swiss have always been great makers of watches, and of late years the Americans have developed a large number of good makes. In America especially, many of the clocks are now run by electricity.

We have seen that the sundial would not work at sea, and the clepsydra was little better. But the hourglass worked pretty well. And time is very important on the sea,



Here is the great clock that makes our time. All the little clocks and watches are just machines for dividing into shorter periods the days that the sun tells off for us as he travels across the sky. Those days are always twenty-four hours long, the length of time it takes the earth to spin completely round. And it always takes just the same number of those days for the earth to make its annual march around the sun and so tell off a year. The moon is an unreliable timepiece, so we no longer pay any attention to her when it comes to setting our watches. But the time system based on the sun is dependable. In the United States it is the Naval Observatory timekeepers at Washington, D. C. who take the time by the sun and send out time signals by radio and telegraph to keep the nation's clocks regulated.

for by means of it the sailor tells how fast his boat is going

In the old days the sailor flung overboard a "log," or piece of wood made to resist the action of the waves, with a string tied to it. In the string there was a series of knots, 50 feet, 7 inches apart. As the sailor threw over the log and felt the first knot slipping through his fingers, he stamped on the deck Instantly another sailor turned up the sand-glass, made to run exactly half a minute. As the last grain of sand ran out, he gave a signal; then the first sailor clamped his fingers on the string and noted the number of knots or parts of a knot that had run through his fingers. He could then say just how fast the ship was going

How Long Is a Sea Mile?

For instance, suppose he was just coming to the second knot as the sand ran out. Then he had gone fifty feet and seven inches in half a minute. That meant that he was going one nautical mile—6,070 feet—an hour. For the nautical mile is longer than the land mile, which has only 5,280 feet. It was made longer in order that it might measure one sixtieth of a degree—and the whole circumference of the earth is 360 degrees.

To-day we say that a ship is making so many knots an hour. But the word is really incorrect We should say so many knots a half minute, or so many nautical miles per hour A sailor says, merely, so many knots.

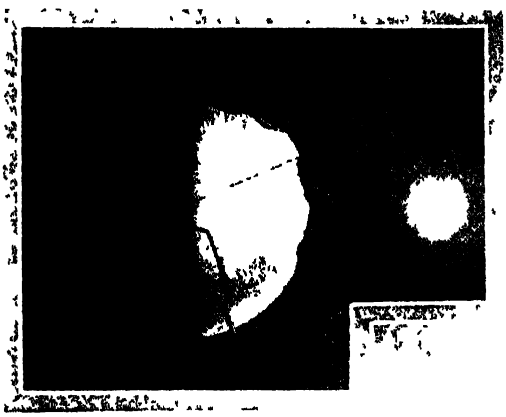
How Time Is Kept at Sea

On the sea the time is kept, not by the hour, but by the "watch." A "watch" is four hours; it is the time that the man in the lookout stays on the "watch." The first watch is from twelve to four, the second from four to eight, and so on; and a bell is rung every half hour. One bell means half past twelve, two bells one o'clock, and so on to eight bells, which is four o'clock. Then the counting starts all over again.

We have said that the sun makes all our time for us. It marks off our days. From the moment when it is overhead at noon to the next moment when it comes around overhead at noon makes one day. If the sun never moved, but always stayed straight overhead, then it would always be day. It would be noon forever, and there would be no such thing as time. Now that is something that most people never think of; but the fact is that if there were nothing moving in the universe, if everything stayed still

forever, there would be no time at all. It would always be just "now." Only as we note how long it takes something to move from one place to another can we tell the time that passes. In this respect, time and motion are the same thing.

So the sun makes our day, and then we divide each day into twenty-four hours, each hour into sixty minutes, and each minute into sixty seconds. We might have chosen any other numbers, but these do well enough. Now all our machines for counting time have just been things that made so many *motions* to the hour. The shadow of the sundial creeps just so far in an hour. The water in the clepsydra and the sand in the hour-glass will spill just so much in an hour. The wheels in the clock or watch will turn just so far in an hour. So time is still motion; and all that we have done to keep better and better time has been to build machines that will keep in step with the sun.

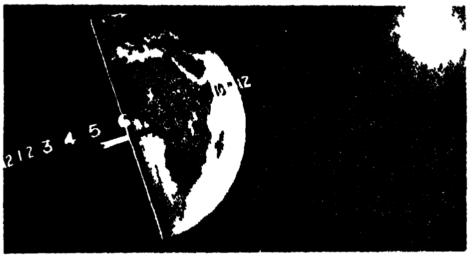


If we reckon our days by the sun, why don't we count from sunrise to sunrise, instead of from noon to noon? It certainly would be the logical way, but there is one great objection. The sun never rises at the same time twice in succession; so our days would never be the same length. This is all because the earth is tilted as it travels round the sun; so in winter the sun is directly overhead in the Southern Hemisphere, as is shown at the left, and days in the Northern Hemisphere are short and cold. But as the earth travels on around the sun and gets to the other side of him, the Northern Hemisphere is tilted toward him. The North Pole would now be at A and the South Pole at B, and the sun to people who live in the north would rise early and set late. There is one time in the day, however, which we can be certain of; that is the moment when the sun is directly over a line that would connect the spot where we are standing with the North and the South Poles. Then it is noon and from noon to noon is twenty-four hours.

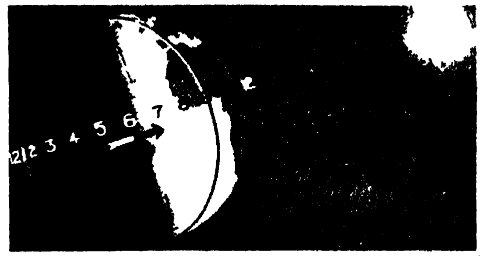
Long ago people used to reckon the day from sunrise. But that did not work well, because the sun keeps rising at different times. So we now reckon from noon, when the sun is at its highest in the sky. From the moment the sun gets there to the next moment it gets there is always twenty-four hours.

There would seem to be nothing unusual about the zigzag line connecting the earth's poles in the picture above, but in reality it is the point at which yesterday turns into to-day and to-day becomes to-morrow. Geographers know it as the International Date Line, or the 180th meridian. It is exactly opposite Greenwich on the earth's surface; so every day whose noon is announced to the world at Greenwich was born twelve hours before on the International Date Line. Or in other words, when it is Sunday on the western side of this line it is Monday on the eastern side. If you could stand on the North Pole and peer down over the side of the earth with Greenwich directly behind you, you would see a sight somewhat like the picture at the right. Around the earth the ships would be going in endless procession, and every ship as it crossed the Date Line would gain or lose a day, depending on whether it was going east or west. If it crossed the line going east on December 31st, one end of the ship would be in the old year and the other end in the new. Of course the Date Line is drawn only on maps—and there it is zigzag, in order that it may not cross any land.

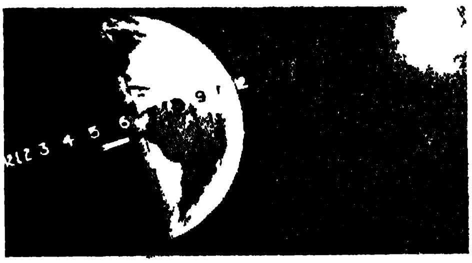
But of course the sun gets there at different moments for different places. When it is noon in London it is not noon in New York, and when it is noon in New York it is early morning in California. So every place must have its own time. That used to be a bit confusing,



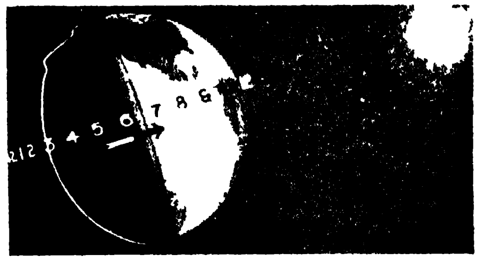
It is noon when the sun is directly over an imaginary line connecting the spot on which you are standing with the North and South Poles Above, it is noon at 12 on the right



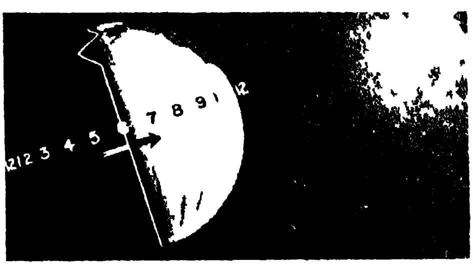
As our globe spins round under the sun, every spot passes beneath him and then leaves him behind. In the picture above, the white line the meridian of Greenwich—is at 9 A M.



Now our globe has spun about until Greenwich, which in our first picture was at 6 o'clock in the morning, is now directly under the sun It is noon there—and morning in America.

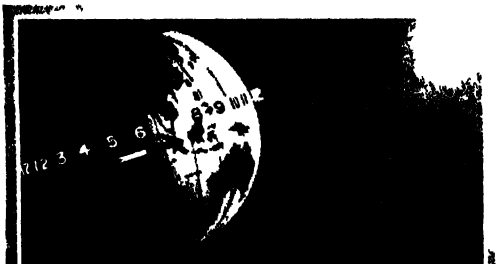


Now America too is swinging along toward noon, and the International Date Line, where it was midnight when it was noon at Greenwich, has now reached three o'clock in the morning.



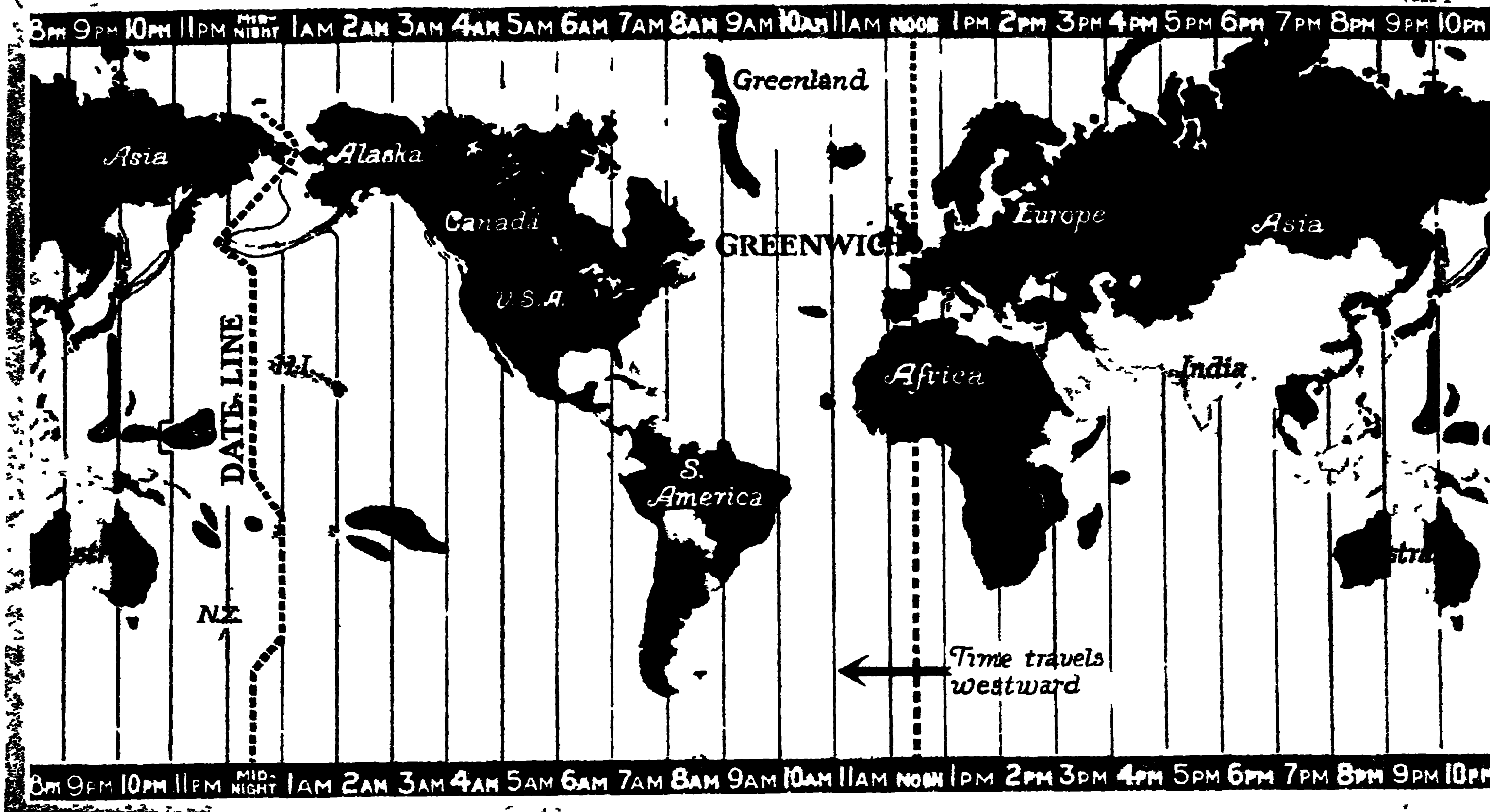
When the International Date Line left midnight behind—shown by the figure 12 at the left—the people along it put a new date on their letters. They were the first to write it

Now all the world you see to the left of the International Date Line is using the new date. But the rest of the world may not use it till after twelve o'clock at midnight.



By now the Date Line is at noon, and at Greenwich it is midnight. In the United States, on the other side of the earth, day is drawing to a close, it is morning in Asia.

Our old earth will soon have swung completely round Greenwich has now reached 3 o'clock A.M., and will soon be having her sunrise at 6—her position in the first picture.



Suppose you could suddenly take the crust off the earth and spread it out flat like this, having slit it from north to south through Eastern Asia. You would still have the whole of the earth's surface, but it would be like a plain. Now let us imagine that lines were drawn north and south just 15 degrees apart All the places between any two lines will be having the same time, but that time will be an hour earlier or later than the time in the spaces on either side So if it were noon along the dotted line that passes through Greenwich—that is, if the sun were straight above that line—it would be 11 A M in the space just west, and 1 P.M. in the space just to the east. "A.M."—ante meridiem—means "before noon", "P.M."—post meridiem—means "after noon." The figures at the top and bottom of each zone show what time it will be in that zone when it is noon in Greenwich But be sure to remember that as soon as you cross the International Date Line, which goes zigzagging north and south across our map at the left, you must step into yesterday if you are going west, and into to-morrow if you are traveling east. For a new day is born every time it is midnight along that line. Countries not shaded on the map do not use Greenwich time.

and it would be so still if we had not found a way to get around the trouble. We can see how hard it would be to run boats across the ocean or fast trains across the continent if the time were always changing as we swept along. Nobody's watch would ever be right.

Now for years the British ships had all run on what we call Greenwich (grĭn'ĭj) time — that is, the time it was at the observatory in the little town of Greenwich, near London. And at last all the world simply agreed to go on Greenwich time—not because it was any better than Paris time or Tokio time, but simply because it was already followed all around the world at sea. Every clock in the world is now set to agree with Greenwich.

What Is Greenwich Time?

As you climb the hill to the observatory at Greenwich, you will see a strip of concrete laid down in your road. It marks the path of a line from the North Pole to the South Pole through that point in Greenwich. It is where longitude begins, and it is where time begins. When the sun gets over that line, it is noon. Anywhere east of there it is later in the day, and anywhere west it is earlier.

Now the whole world is divided up into 360 degrees of longitude. And since a day has twenty-four hours, or 1,440 minutes, we can see by dividing that we have to allow four minutes for each degree. That is the time it takes the sun to pass over one degree. So one degree east of Greenwich it would be four minutes later than at Greenwich, and one degree west it would be four minutes earlier. Fifteen degrees away it would be one hour earlier or later.

How Time Changes on a Ship

If you were traveling west from Greenwich you would therefore have to set your watch back four minutes every time you went one degree; and if you were going east, you would set it four minutes forward. But it would be a nuisance to keep setting your watch every hour or two. So what happens is that everyone agrees to set his watch back once a day; and on a boat coming to New York, about the first thing you do in the morning is to find out what time it is and set your watch. How much you set it back depends on the speed of the boat. On the fast ships you will set it back about an hour.

On the land you do not set the watch back every morning, but every time you have gone a certain distance, or crossed a certain line. For that purpose the whole United States is divided into four time belts, each fifteen degrees wide. As you cross from one into another, you change your watch one hour. In going from New York to California you would therefore set it back three times, and gain three hours. If you were coming the other way, you would set it forward, and lose your hours. The four time belts give us Eastern, Central, Mountain, and Pacific time. Anywhere in one belt it is always the same time; in the next one it is an hour earlier or later; but in them all it is always Greenwich time —with the proper number of hours added or subtracted.

Now if you kept going west and gaining an hour every so often, you would gain twenty-four hours after a while. You would gain a whole day—and then it would be yesterday! And if you kept going east, it would soon be to-morrow. What would you do when to-day turns into yesterday?

Where To-day Becomes Yesterday

Well, you would simply have to call it yesterday, and let it go at that. And this is exactly what happens. In the middle of the Pacific Ocean, along the 180th degree of longitude and just opposite Greenwich on the world's surface, there is an imaginary line, drawn zigzag to keep it from going through any island. When you cross that line going west, you lose a day. If it is Monday, you just call it Tuesday. And of course if you are going east, you gain a day and call it Sunday. Otherwise an aviator who kept going east would soon be back in the middle of last month!

Just before ten o'clock every morning and six o'clock every evening, the great Rugby broadcasting station in England stops sending and switches into Greenwich. And then comes the signal, audible anywhere on sea or land, to say that it is ten o'clock or six o'clock at Greenwich, where the time begins. So twice a day the world is put in harmony of time, or in tune with the sun.

Reading Unit No. 17

THE UNRULY CALENDAR

Note: For basic information not found on this page, consult the general Index, Vol. 15.

For statistical and current facts, consult the Richards Year Book Index.

Interesting Facts Explained

Related Material

Practical Applications

Leisure-time Activities

PROJECT NO. 1: Copy the calendar made by the Dakota Indians, 10–479

PROJECT NO. 2: Make a clay model of the Mayan calendar, 10–477

Summary Statement

As man advanced along the road to civilization he learned to record time by writing on clay, wood, or stone. But finally a calendar was worked out by sun time which gave us our days, months, and years—and we added the weeks to complete the scheme.

Photo by the artist David C. Lithgow

They are seeing their god face to face. For these are sun worshipers, who, knowing as yet no higher power than the great glowing disk that gives them food and comfort, look upon it with the reverence that all mankind, in a savage state, feel for the forces of nature. Is it strange that these devout worshipers will watch their god through all his yearly changes, and learn to reckon time by his movements?

The UNRULY CALENDAR

Father Time Has Long Had His Troubles in Making the Days Fit the Years and the Months Stay in Their Places

ANYONE who has ever tried to count thousands of little dots all ranged along in a row knows how hard it is to keep track of them. He gets all mixed up, and often he has to begin over and over again. Now mankind has had just the same trouble trying to keep track of the passing days—only the problem really has been much harder, for once a day is gone, it will never come back again to be counted. You remember that Robinson Crusoe made a notch in a piece of wood every day. Then he could count the notches. And whole nations have done the same thing, using stone instead of wood.

But keeping trace of the days is easy in comparison with trying to find a way to point out a given day, once it is gone forever. For we must remember that early men were not born to a carefully worked-out calendar of days and months and years, all running smoothly year after year. All they had was a long series of sun risings and sun settings on and on and on, each day treading on the heels of the day before and, except for the change of the seasons, all of them very much alike.

It was the constant march of winter and spring and summer and autumn that brought variety to early men. And we feel the excitement of it even to-day. Who would be willing to part with the thrill of the first warm day of spring, or the soft hush of the first snowfall? In the lives of early men those were very great events. "Six snows has this child seen," the proud Indian squaw says of her boy. She means he is six years old.

That sort of reckoning was all the early peoples needed to go by—"winters" in the north, "rains" in the tropics, or "winds" in

the lands where the breeze blows from the same quarter for six months on end. Sometimes men might even refer to the years as "harvests." But whatever they reckoned as the beginning of a "year," it was always something that was bound to happen over and over again. Of course they had no notion of the exact number of days from "harvest" to "harvest" or from "snow" to "snow." How could they have? The first snow falls whenever Mother Nature is ready! Summer was "when the thistle blooms"; winter began when the leaves fell from the trees. And most tribes had only two seasons, winter and summer, or a wet season and a dry season. Only a few of them added spring and autumn.

But though it was hard to tell the days apart, it was harder still to tell one year from another. You see, there were no written records. Men had not even learned to count very far. But there were certain events in their own lives that no one could forget--a great war, a pestilence, a famine. Perhaps a whole tribe picked up its goods and traveled into a far country. For a long time after any upheaval of that sort everyone counted the years from the great event. And then some other upheaval came along, and they began to reckon anew. Every fifteen or twenty years they would start all over again.

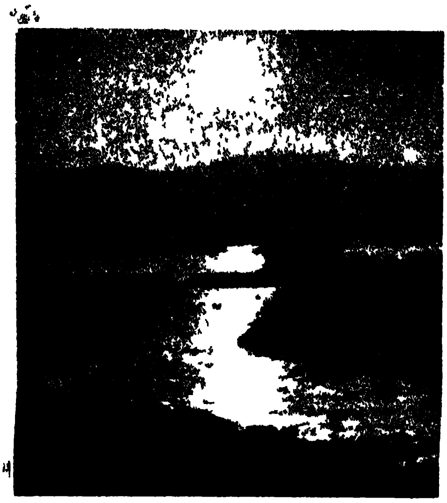


Photo by Swedish State Rys

This pretty scene is from Lapland; but it is not a sunrise nor yet a sunset, for those things are managed differently in the land of the reindeer. The photograph was taken at half past one in the morning, and this is the famous sun that shines at midnight in the arctic regions, where one day and one night make a year, since the day and night are each six months long.

When Our Calendar Began

History was a good deal simpler in those days. No dates to remember then! If anything happened that was worth keeping track of, the tribal priest probably remembered it as having taken place on "the day of the full moon, in the month of the falling leaves, in the year of the cattle disease"—or in some way equally poetic. And even that was probably more definite than it needed to be!

As men advanced farther along the road to civilization and learned how to leave records for their great-great-great-great grandchildren by means of marks on clay or wood or stone, they began a new reckoning every time a new king came to the throne. So the "third year of Darius" meant the third year of Darius' reign.

Finally, about the year 900 A.D., as we reckon time, all Christian peoples decided to count the years forward and backward from the birth of Christ. So they tried to figure out as nearly as they could just when Christ was born, and then they named the first year following as the year 1 Anno Domini (ăn'ō dŏm'ĭ-nī), which is the Latin for "in the year of our Lord." The year before that they called 1 before Christ; and these have been abbreviated to read 1 A.D. and 1 B.C. As we go back into history before the birth of Christ, we have to count backward, and in the years after his birth we count straight ahead.

When Was the Year One?

As a matter of fact, we know now that the men who fixed the year 1 made an error in fixing the date of Jesus' birth, and put it several years too late; but we have never changed the calendar and corrected the mistake.

A good many peoples still count from some other important date. The Mohammedans have chosen a year in the life of their prophet Mohammed, and the Jews count back to a date 3,760 years before the birth of Christ. Long ago they believed that their year 1

was the year of the creation of the world. But we now know that the Egyptians were living in the Nile Valley long before the year 1 of the Hebrews. For in 4241 B.C. the Egyptians were highly enough civilized to start a written record of their deeds; and they began their calendar at that time. It is the oldest date in history. Their year was much like ours; they had learned that it had 365 days, which they divided into twelve months. But they had no weeks, and they never had a leap year.

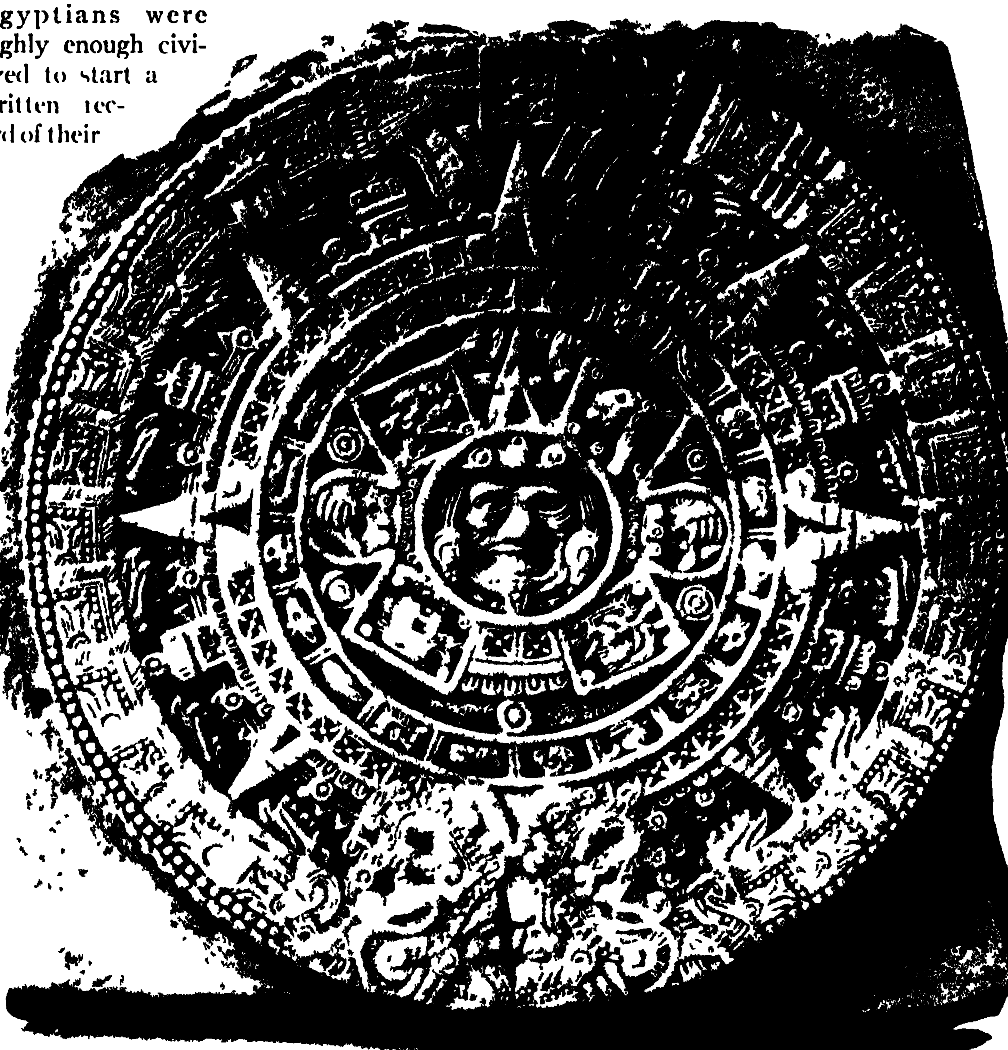


Photo by National Museum

Long before white men appeared in America the Aztecs in Mexico had worked out an ingenious way for keeping track of the time. They divided their year into eighteen months of twenty days each, with five extra days to round out the year; and they kept track of their calendar on huge round stones carved with many figures. The most wonderful of all these stones is shown above. It was called "The Rock of the Sun," and was carved out of solid basalt for a magnificent temple dedicated in 1481. Its diameter is 11 feet, 8 inches, and its weight some 27 tons. The head in the center represents the sun, and the four squares set in the circle around him are the four seasons. The little squares in the next circle are the twenty days of the month—each day with a different name. Other circles show various signs connected with the record of the years and with the sixteen hours into which the day and night were divided. The stone was painted red, because that color represented the sun. It is now in Mexico City.

Of course by the time people have learned to keep a written record of events, they have probably learned that it is the sun that makes the years, as well as the days. For they have watched and watched, and counted their notches in a piece of wood or stone, till

they are sure that it takes the sun 365 days to travel south from his point highest overhead and back again; we know to-day that it is the length of time the earth takes to travel round the sun. But long before they have timed its year-long journey, they have noticed something else that happens in the sky.

For who could miss the moon? Every 29½ days she makes her first appearance as a dainty crescent and for nearly four weeks she keeps changing her shape from day to day, until she finally becomes a crescent once more. For in that length of time she has made her monthly journey round the earth. Now it will be easy to see that long before the simple minds of early men learned to count to 365, or to measure the sun's lagging march north and south in the sky, they must have learned to time the phases of the moon.

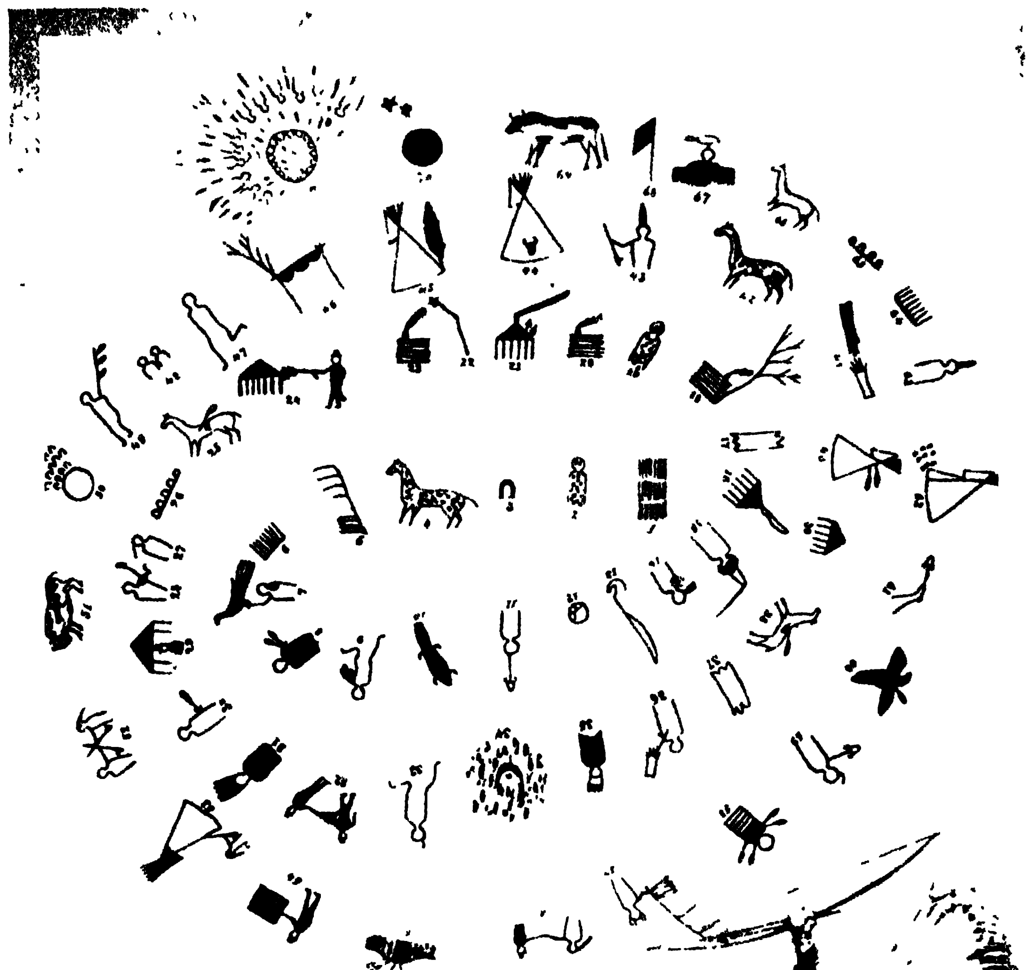
Three times on all ten fingers—and there was her crescent again in the western sky! How much simpler to count by "moon trips" than by "sun trips!"

What Is a Month?

So that was what they did—and so they got their "months." The very word comes from "moon," the great heavenly clock that

We think of the New World as having a very short history, yet this carved stone, the oldest American antiquity to which we can give a date with certainty, has come down to us from a century before Christ. It is covered with writing of the Maya (ma'yá) race, who lived in Central America and Southern Mexico and were the most highly civilized of all the American Indians. The figure standing beside the stone is one of a group of Mayas shown in the National Museum. This great stone calendar is carved in jadeite, and bears the Mayan date 8.6.2.4.17 8 Caban O Kankin—or 98 B.C. It is known as the Tuxtla Statuette, for it represents a birdlike god with a human head and was found near Tuxtla, Mexico.

Photos by National Museum



This is a calendar of the Dakota Indians, kept on an official buffalo robe by Lone Dog, who as a youth was appointed by his tribe to make a record of each passing year. So between 1799 and 1870 he annually set down an important event, in the manner shown above, to keep the "winter count" of the tribe. Those events are numbered in order. Here is the meaning of a few of them: 1. Thirty Dakotas killed in 1799 by Crow Indians. 2. Smallpox among Dakotas. 3. Dakotas stole horses wearing shoes. 4. Dakotas stole horses with tufted curly hair. 8. Chief Red Coat killed. 9. A Dakota killed by two arrows while running. 13. Wild horses lassoed. 14. Epidemic of whooping cough. 16. Chief Crow Feather built dirt lodge at Peoria Bottom. 17. Plenty of buffalo meat. 18. A Canadian built a trading store of dry timber. 19. Many died of measles. 22. Meteor or comet seen. 24. White soldiers appeared for first time. 28. Dead Arm was stabbed with a dirk. 29. A white man built a dirt lodge. 33. Lone Horn crippled in the leg. 34. Meteoric showers. 38. A hundred elk killed in one hunt. 40. Dakotas massacred village of Snake Indians. 41. Peace made with Cheyennes. 44. Dakotas held ceremony to bring back the buffaloes. 45. Fort built of pine timbers. 46. Plenty of buffalo meat for drying. 49. A humpback was killed. 52. Dakotas and Crows exchanged peace pipes. 56. Gen. Harney made peace with bands of Dakotas. 58. Dakotas killed a Crow squaw. 62. Buffaloes came close to the wigwams. 68. United States peace commissioners visited tribe. 70. Eclipse of the sun. 71. Dakotas attacked fort of Crows.

Photos by Mentor Magazine and Ranier National Park

measures off every 29½ days. It was natural enough for the moon of any given season to be named for whatever events she saw here on earth at that time—the "moon of blackberries," the "moon of lambs," when the little things were born, the "moon of falling leaves." We still speak of the Easter moon, the harvest moon, and the hunter's moon. In this way the months were named, and came to make a very fair calendar to mark the circle of the year.

The Unruly Moon

And then everything began to go wrong! For the moon and sun run on quite different schedules, and their periods do not come out even at all. Just try to divide 365 by 29½. Sometimes there were twelve new moons in a year and sometimes thirteen. What was one to do about it?

And one thing having gone wrong, everything seemed to get perverse. The calendar of the sun, which had seemed to start off quite nicely with 365 days in the year, all rolling around with great regularity, now began to behave in an unruly way. In spite of all one could do, it kept on sliding backward, for the year runs a little longer than 365 days. There are 5 hours, 48 minutes, and 46 seconds left over after every year of 365 days—and after a while these extra periods mount up to something quite impressive. In ten years the first of January in the early calendar would have moved back to what ought to have been the twenty-ninth of December, and in two hundred years it would be back somewhere in November. In due time Christmas would have been coming around in midsummer. We can almost fancy the ancient Egyptians saying to each other, after their calendar had been going for several hundred years, "This is a hot day for the tenth of December. It feels more like August!" And of course it would really be August, or whatever the Egyptians called the month. For their calendar year was almost six hours too short.

The people did not like to have the months sliding around in that way, but try as they would they could not find out how to straighten things out. So they finally gave up in despair and let the months have their own way. About every fifteen hundred years the first of January would come back to the first of January. All the rest of the time it was somewhere else!

The Egyptians Kept Star Time

But even then the Egyptian calendar worked better than any of the other early calendars. Theirs was the first one ever made; and it was very clever. Instead of running on sun time, they ran it by the bright star Sirius, which of course keeps the same time as the sun. The day when Sirius first showed his face above the eastern desert, after a long absence, was their New Year's Day—and it was usually an important season, for about that time the Nile too began to rise,

These Mayan men were sure that they were setting down the first date in history. They did not know that for four thousand years people had already been keeping records along the Nile.

Photo by National Museum

Photo by American Museum of Natural History

It was in the land of the sphinx that our calendar began For in Egypt men first worked out a convenient system for keeping track of time; and in 4241 B.C., the oldest date we have, they began a written history.

and to bring them moisture and fertile soil for another year.

Of course they realized that the months would not fit in at all, but they took the extra days left over after twelve moons had passed and distributed them over the various months, much as we do to-day. To be sure, that left the moon quite out of things so far as the calendar went, but at least it was convenient to have the years and the months all come out even every New Year's Day.

When Babylon Ran on Moon Time

The Babylonians, who had a calendar four thousand years ago, tried to run things by the moon and they had a bad time of it! The moon has always been unwilling to keep a fixed appointment with the sun, so the months and years each had to take their own separate ways. There was no telling in what month New Year's Day might come.

The Babylonians passed their calendar on to the Greeks, who did not like it much; but since it was all they had, they struggled with it for seven hundred years and then hit on the plan of having twelve moon months in every year and adding three extra moon months every eight years. This did not work very well either, and there were quarrels now and then as to what time of year it was; but it was an improvement on the Babylonian plan.

Like the Greeks, the early Romans also ran on moon time. At first they had only ten months in a year, and let the extra time go, but after a while they managed to squeeze twelve well-behaved months into their calendar, though they made the mistake of giving the year 360 days. Of course this made the year too long by some eighteen hours. So every now and then they had to drop a few days in order to set themselves right again. Even then the calendar was three months out of schedule at the time when Julius Caesar was ruling, some two thousand years ago.

How the Months Got Their Names

Caesar was too good an organizer to like such a state of affairs. He was an energetic man; so on the advice of his astronomers he gave the year 365 days and added an extra day every fourth year, in order to catch up with the sun. That fourth year we call leap

year. Caesar straightened things out pretty well, though not entirely.

It was from the Roman calendar that we took the names for our months. The first month they named for Janus, a god who had two faces, one before and one behind, and so guarded doors and gates, since he could look two ways at once. Februa was the name of a Roman festival of purification. Mars, who gave his name to our March, was the god of war; and Aprilis was their name for the month that followed. Maia was a goddess for whom they named their fifth month; and Juno, from whose name we get our "June," was the wife of Jupiter, king of all the gods. July was named for the great Julius himself, and August for Augustus Caesar.

How February Lost a Day

Perhaps we might say here that at first August had only thirty days. But the great Augustus was not great enough to master all his childish vanity. He could not bear it that Julius Caesar's month, July, should have thirty-one days and his own but thirty. So February was robbed of a day, which was tacked on to August. Then the great man was happier!

The rest of the months get their names from the Latin for "seventh," "eighth," "ninth," and "tenth." As the Romans counted, those were the seventh, eighth, ninth, and tenth months, for the Roman year at first had only ten months. At first the Roman year had opened in the spring, which seems to be the natural time; but later the opening was fixed at January 1st, for it was then that the new consuls took office in Rome.

A Rhyme Worth Remembering

We get the name of our calendar from the Romans, too. It comes from the Latin word "kalendae," the name the Romans gave to the first day of the month. It meant "callings"; for on that day the priests called out from the Capitol at Rome the fact that the new moon had appeared. One of the days of the Roman month was called the "ides"—and the eighth day before it the "nones."

If you will learn the quaint old rhyme which follows, you will never have any trouble remembering how many days are in a given month:

> Thirty days hath September,
> April, June, and November;
> All the others, thirty-one
> Except the second month alone,
> Which hath but twenty-eight, in fine,
> Till leap year gives it twenty-nine.

Under the Julian calendar things went fairly smoothly for a long time. But the calendar was not perfect yet, and by 1582 it was jolting rather badly, for every 128 years it was gaining a day. So at that time Pope Gregory XIII took ten days out of the calendar and decided to omit leap year once in every hundred years, but to keep it in all those years that can be divided by 400. All other years are leap years if the number of the year can be divided by 4. So 1900 was not a leap year, but the year 2000 will be, as will the years 2400, 2800, and so on.

Even so, the calendar is running just a trifle ahead of the sun; every year it gains twenty-six seconds, which amounts to a day in every 3,323 years. People will probably drop a day when the year 4000 arrives.

How the Days Got Their Names

Nearly all the countries now follow the plan of Gregory XIII - which we call the Gregorian (grē-gō'rĭ-ăn) calendar. Only in backward or very remote places are other strange calendars used. Since Julius Caesar gave up the moon as timekeeper, the sun has reigned supreme over his unruly family of days and months and years, and without the moon to interfere, they all get along together happily. Of course the weeks still stubbornly refuse to fit into the scheme. Seven never would go evenly into 365, and it is safe to say that it never will!

But the weeks have nothing to do with either sun or moon. They are just a product of men's minds. So certain tribes have "weeks" that are three days long, others four or five or six, all the way up to ten. A great many Eastern peoples, among them the Hebrews, had a week that was seven days long, probably because of the seven "roving" heavenly bodies that were then known to man.

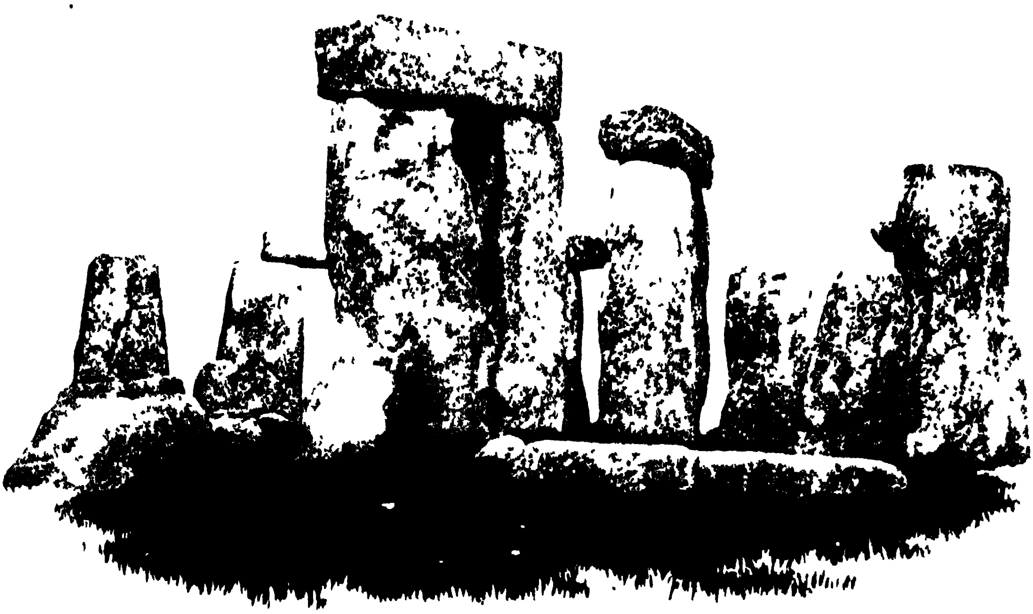


Photo by American Museum of Natural History

This may not look much like a calendar, but that is what it is a calendar made to mark just one day in the year. Of course it served other purposes besides, for no one would ever have taken the trouble to hew out and set up all those great stones—some 140 originally—if they had not served a very important end. There is still some debate as to just what that end was, but it is now fairly certain that this mysterious relic of the hoary days of eld was a Druid temple used in the worship of the sun and quite probably the scene of magic rites connected with the dead. To-day we call it Stonehenge, and thousands of visitors flock every year to beautiful Salisbury Plain in Southern England to see this imposing circle of stones, which has probably stood since about 1700 B.C. It never had a roof. A long avenue led from the northeast to a circle of earthworks 300 feet in diameter. Inside this was a circle 108 feet across made of gigantic oblong stones called "sarsens," all set on end with big stones laid like crossbeams on the tops of them. Nine feet inside this circle was a smaller circle of stones of a different kind brought from no one knows where. Inside this was a horseshoe of huge stones with crossbeams, with another horseshoe of smaller stones inside it. And in this central inclosure was the great altar stone. Anyone standing in front of the altar on the longest day in the year and sighting along the avenue to the northeast would see the sun rising directly over a stone marker set outside the circles. That must have been the Druids' great day.

Even the names of our own week days come from the names of those heavenly bodies the sun and moon and the five planets that early men had found. To be sure, the heathen Anglo-Saxons, who were the first people to speak English, translated the names of those planets into the names of certain of their own gods, but they were careful to choose gods that stood for the same things as the old gods for which the planets had been named.

Why We Have a Week

So what in Rome had been the sun's day became our Sunday; the moon's day became our Monday—a shortened form. The day of Mars became the day of Tiw, or Tuesday; the day of Mercury became the day of Woden, or Wednesday; the day of Jove became the day of Thor, or Thursday; the day of Venus became the day of Frigg, or Friday; and the day of Saturn became the day of Seterne, or Saturday.

Perhaps we may feel that an error of one day in every 3,323 years is very small indeed, and that our calendar is about as perfect as it could be made. And yet our calendar is so inconvenient that certain big business organizations have changed it greatly for their own use inside the organization. They operate on a schedule of thirteen months of exactly four weeks, or twenty-eight days, each. At the end of the year there is one day to spare. This scheme is so convenient that it will probably be used more and more—and in the end it may come to be the calendar for all the world. Then Christmas and Fourth of July and New Year's Day and your birthday will always come on the same day of the week, year after year. And the day that is left over? Well, what better holiday could one want?

The STORY *of the* MICROSCOPE

Reading Unit
No. 18

THE WINDOW INTO FAIRYLAND

Note: For basic information not found on this page, consult the general Index, Vol. 15.

For statistical and current facts, consult the Richards Year Book Index.

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Things to Think About

How many times bigger can objects be made to appear under the microscope?

Why are lenses made of crown and flint glass?

What kind of wonders can we see through the microscope?

Why is it important to know about the tiny creatures we can see under the microscope?

Picture Hunt

How does a compound microscope work? 10-486

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Practical Applications

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How has the microscope helped us to make strong steel? 10-490

Summary Statement

Not only has the microscope helped us in the useful arts, but it has also taken the terror out of many a dread disease.

Do you care to take a trip to another world? Then just look through this microscope and you may see a drop of water changed into a pond where strange monsters glide about and turn somersaults in their search for food. Even in this tiny world the "large" creatures prey upon the smaller ones, which, in turn, find something even smaller to fill their stomachs with– if the odd creatures are lucky enough to own a stomach!

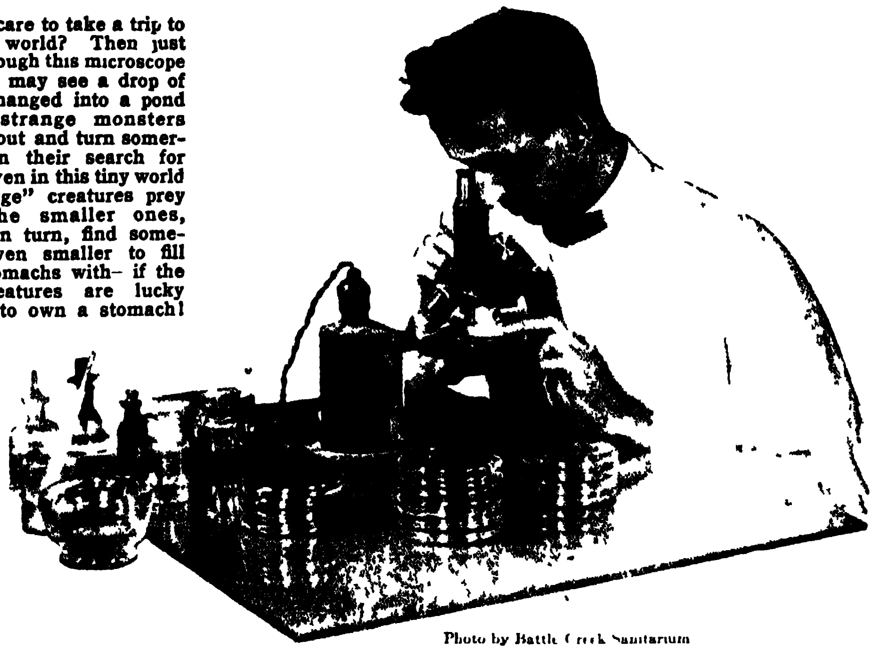


Photo by Battle Creek Sanitarium

The WINDOW *into* FAIRYLAND

Through the Eyepiece of the Microscope We Can See More Creatures in a Spoonful of Water than Our Own Eyes Could Find in a Whole Pond

ALL around us there are millions and billions of living and moving things that we never see They are climbing over our hands and faces, swimming in our milk and water, and dancing just before our eyes, without our ever dreaming of them. It is all because they are too small. For we can see a thing only as it reflects the light– which is why we cannot see at all in the pitch dark and these things are so tiny that they cannot reflect enough light to make any impression on our eyes.

So we never knew they were there at all until we found an instrument to show them to us. We call it the microscope, from two Greek words meaning to "see small" And with a microscope we can look at billions of swarming creatures too small ever to be seen in any other way.

Now the way a microscope works is very easy to explain. The nearer a thing comes to our eye, the bigger it looks to us. Thus a little coin held close enough may well look larger than the moon, and even a grain of sand may blot out the biggest star. But on the other hand, when we bring a thing too close to the eye we cannot see it clearly any longer It is just a blur. That is because our eye cannot focus on a thing that is too near to it

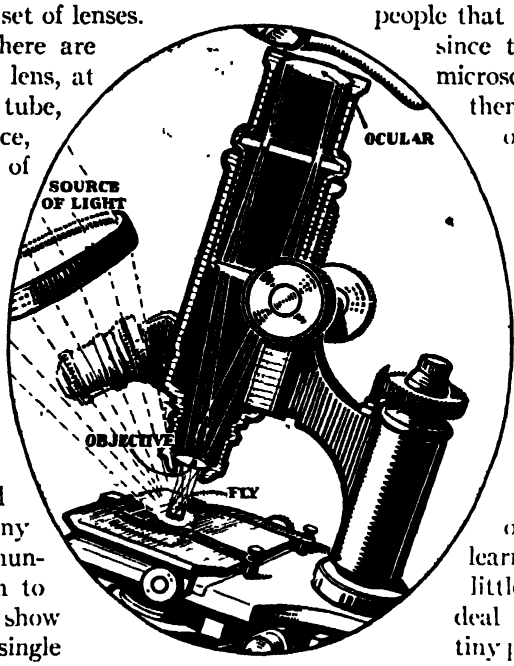
So even if we could bring the tiniest things near enough to see, we should still not see them because then they would be only blurs What the microscope does is to let us see them as if they were very near and still very clear. And this it does through the lens, or set of lenses, that it carries. With these it can bring a bee's tongue, for instance, to a quarter of an inch from the eye; but it can also keep the image in perfect focus at that point, so that we see it as clearly as if it were a foot away. And then the bee's tongue looks half an inch long!

Of course the lenses do not really *bring* the thing nearer. As you may see in the picture, they just manage the rays of light reflected from the thing so as to make it *look* nearer, or bigger. In a simple microscope there is only one set of lenses. In a compound one there are two; first the objective lens, at the far end of the brass tube, and second the eyepiece, at the near end. Both of these serve to magnify the thing we are looking at.

A simple microscope may make things look a hundred times bigger than they are. A compound one may make them look five thousand times larger. A fine instrument will show us creatures so tiny that it would take a hundred thousand of them to stretch an inch. It may show us more of them in a single drop of water than all the fish in a whole lake.

To see a thing through the microscope we first put it between two pieces of thin glass. Then we put the glass just under the tube of the instrument and throw a bright light on it. We get the right focus in the same sort of way as with an opera glass—and then we see wonders!

A single drop of water from a puddle will reveal all sorts of queer and curious creatures swimming around in it. The front leg of a bee will show us the brush and comb he carries for cleaning his antennae, or feelers. The wing of a butterfly will be seen covered with a host of tiny scales that come off in dust if we touch them. The edge of the sharpest razor blade will look as rough as that of a carpenter's saw. And a whole magic universe of tiny beings comes into view—so numerous that all the population of the world will seem as nothing in comparison. At any moment any one of us is entertaining in his body a far greater number of these creatures than the number of all the people that have lived in the world since time began. With the microscope we not only see them, but can take pictures of them.



The picture above shows how a compound microscope works. Light is directed upon the object to be magnified—in this case a fly. The rays of light from the object pass through the "objective lens," which produces a reversed magnified image, so that your fly, grown much larger, looks as though he were facing in the opposite direction. Passing through the eyepiece, or "ocular," this image is magnified still more and the fly now becomes the giant of his race! The wheel-like objects to the right of the microscope barrel are screws which can be turned to adjust the microscope to a proper focus. The arrangement of lenses can be very complicated; one or two or more can be used in either the objective or the eyepiece. This is done to correct various defects in magnification, and to make the image clear. To understand how the lenses work, both separately and together, you must turn to our pages on physics and learn about light.

It is most important to know about these tiny creatures. They have taught us a vast part of what we now know about life; for they are so small and simple that in them, so to speak, we can study life in its beginnings. Much of what we know about our own bodies we have learned by watching these little beings and a great deal more by watching the tiny parts, or cells, that make up our own flesh and bone. A little speck of our own blood under a microscope will tell us a good deal about what happens inside us when we are playing football or going into battle, when we are coming into a fortune or falling in love.

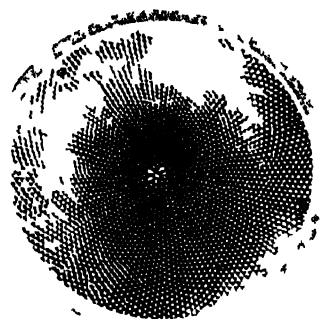
Many of the tiny creatures in us and around us are good for us, and we cannot live without them. Some of them are very bad for us, and will make us ill or kill us if they invade us. So it is most important to know about them and to find out how to encourage the good ones and kill off the bad ones. Without the microscope we could never have begun this, for we should never have dreamed that the creatures existed. Many a dread disease like rabies or diphtheria has lost its terrors since the microscope, and many another is still to have its fangs drawn. Never again shall we

Protozoa, tiny one-celled animals.

A snowflake, of course, magnified

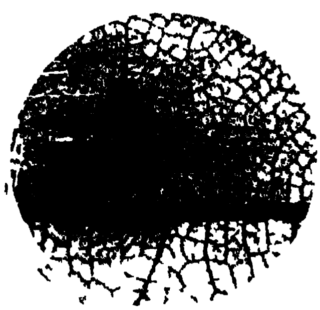
A tick found on sheep.

Radiolarian, a tiny animal of the sea.

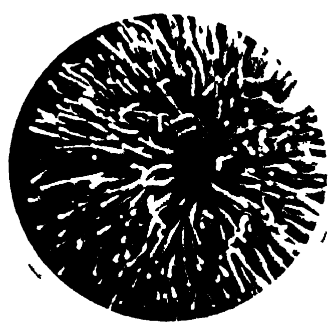


Diatom, a tiny one celled water plant

A snowflake, magnified, as are all these pictures.

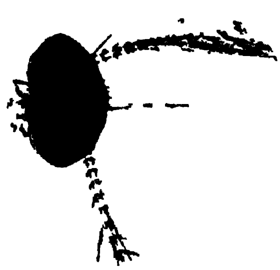


The surface of an oak leaf



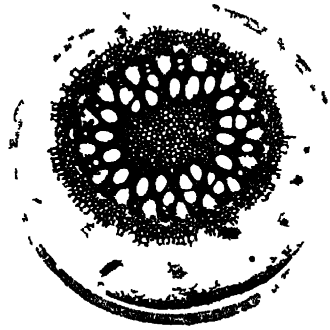
A mushroom coral.

Cross section of a stem



"Close-up" of a flea's head.

Jack Frost's work on a windowpane.



Cross section of a root.

Photos by General Biological Supply House and others

suppose that any sick man has been invaded by some sort of "devil"; we shall know that he is a prey to tiny bacteria (băk-tē'rĭ-à).

And the microscope has done a great deal more besides. It has helped us to make strong steel by letting us see just what happens in the minute particles of the metal we are casting. In the same way it has aided us in making paper, in dyeing cloth, in keeping our foods pure, and in hundreds of other useful arts. So our world is very different since we found out how to see the little things in it a hundred thousand times as big as they really are.

Things Too Tiny to Be Seen

In theory, at least, a microscope could be made to show the tiniest thing in all the world. But there are still billions upon billions of things that no one has ever seen. For in practice no microscope has ever been made that would come anywhere near showing atoms or electrons—those tiniest particles of matter out of which all the universe is made.

Yet even these minutest particles will so affect the light that something like their "shadows" may be seen—through a fine instrument that we call the ultramicroscope. With this we can learn something of the action of the dancing particles and peer still deeper into the universe beyond the eye.

What a far cry from the simple magnifying glass of long ago! They had that as far back as Nineveh, where they used a rock crystal for the purpose. Down through the centuries they kept doing what they could with magnifying lenses of one sort or another.

What Was a "Spying Tube"?

But not until 1590 did anyone think of putting one lens behind another so as to make an early microscope. Then a spectacle maker of Holland named Janssen made a "spying tube." It could magnify about thirty times. Next came another Dutchman named Leeuwenhoek (lā'vĕn-ho͝ok) in 1673 to build a great many simple microscopes and to prove from them that flies and other creatures like them are hatched from eggs and do not just come to life out of nothing, as had been commonly supposed before. Leeuwenhoek is called the father of the science of the microscope.

For a long time there was no further improvement in the instrument. It was hard to get lenses that were good enough. An ordinary glass blurs at the edges and flashes all the colors of the rainbow on the object under observation. But all this was overcome when we began to make the lenses out of crown and flint glass combined.

About 1742 Benjamin Martin made a remarkable instrument with twenty-four lenses. It was the best microscope that had been known up to its time. From then on the lenses were steadily improved and the microscope grew better and better until at last our modern instrument came to its present perfection.

Microscopes which use lenses to get their magnification are called optical microscopes. Optical microscopes serve their purpose well, but scientists soon discovered that they have only a limited power to magnify. The limit is set because light moves in waves. We see an object only when light from that object enters our eyes. If the object is definitely smaller than a single wave length of light, the light skips past the object and is not reflected from it. When that happens, no light from the object enters our eyes. So we cannot see the object.

How a Stain Helps Us to See

From careful calculations, scientists estimate that, with even the most powerful microscope, the smallest particle we could see must have a length of at least one-third of the wave length of the light used, or about 1/125,000 of an inch. The magnification of microscopes is stated in diameters. If through a microscope we look at a single tiny animal one one-hundredth of an inch long and find that the animal looks to be one inch long, we say that the magnification is 100 diameters—$\times$100. Optical microscopes can be used at magnifications of 1,800 diameters when the object to be magnified is stained with a color that makes its details stand out clearly. Higher magnifications up to 500 diameters are possible only when we are looking at objects that show very great contrast.

An amoeba; the simplest form of animal.

The tongue of a fly; much enlarged.

Bacillus that causes milk to sour.

The wing of the painted lady butterfly.

Cross section of mahogany wood.

The sting of the honey bee.

Photos by General Biological Supply House, and others

Now if all the above is true, it would have to follow that if we could make use of light that had a shorter wave length than ordinary sunlight we could see smaller particles through the microscope. Working on this principle scientists invented (1900) the ultramicroscope we have mentioned—a microscope which uses ultraviolet light instead of visible light. In this microscope the eye does not see the image directly. Instead, a photographic plate that is sensitive to ultraviolet light registers the picture. Objects can be magnified 7,500 times with the ultramicroscope.

The Puzzling Viruses

Soon after the ultramicroscope was invented scientists began to try to improve upon it, but they had little success. We had already learned about diseases spread by viruses, in which the particles were so small that they went through all the ordinary filters. Knowing how tiny such particles must be, the scientists held out little hope that we should ever be able to see them.

It was not until 1932 that two Germans, E. Bruche (brü'kē) and H. Johannson, by making use of experiments dating back to 1898, were able to produce the first electron-formed images by using high-voltage electron beams. To-day we have electron microscopes that magnify more than 100,000 times.

The Electron Microscope

The basic principle upon which the operation of the electron microscope depends comes from a discovery which we have already found to be useful. That is Edison's discovery that electrons are thrown off by a heated filament—such as the wire in an electric bulb. Scientists soon found out that electrons coming from the hot filament could be formed into a beam by a magnetic or electrostatic (ē-lĕk'trô-stăt'ĭk) field. On other pages we have told you all about electricity, electrons, and electronic tubes.

The optical and electron microscopes are built in much the same way. Lenses in the optical microscope reproduce and enlarge

an object by taking light originating from a given point on the object and focusing it once again to a point. In the electron microscope the electrons take the place of light. The "lenses" of the electron microscope are what are known as solenoid (sō′-lĕ-noid) electromagnets. It is possible to use the field of a doughnut-shaped magnetic coil to bend the paths of electron rays and focus them on a point. Magnetic lenses of this type form an enlarged image in very much the same way that optical lenses do.

In the optical microscope the source of light is generally a lamp of some kind. The light rays from the lamp are first formed into a parallel beam by a condenser lens and are then directed at the object to be magnified. The objective lens picks up the light which passes through the object and gives us a magnified image. An eyepiece lens further magnifies the already enlarged image and focuses it for the eye to see.

In the electron microscope the hot filament that gives off electrons is the source of illumination. The electrons are passed through a hole in a positively charged plate. This gives them high speed. A doughnut-shaped coil produces a magnetic field that bends the paths of the electrons, forming them into a parallel beam directed at the object we want to look at. Electron rays pass through the object and in so doing are affected in varying degrees, depending upon the thickness and structure of the object. Another solenoid then focuses the electron rays that pass through the specimen we are looking at and causes them to form an enlarged image. A third coil further spreads the electron beam from a small portion of the already magnified image, and so produces a still larger image. The three coils of the electron microscope act very much as the condenser, objective, and eyepiece lenses act in an optical microscope.

The image in the electron microscope may be seen when the electron beam falls upon a fluorescent (floo′ō-rĕs′ĕnt) screen which is a good deal like the one used in a television receiver. Such a screen is made of material that will itself give off light when it is exposed to certain kinds of rays. Photographs can be made by allowing the beam to fall directly on a photographic plate.

One difficulty in the use of an electron microscope lies in the fact that we can operate the electron system only in a vacuum. After we have inserted each specimen into the microscope we must pump out the air, a process that takes several minutes and needs an extensive pumping equipment. But in spite of difficulties the electron microscope is serving medicine and industry. A new model using 300,000-volt electrons promises to give us fresh information as to the nature of many materials.

You may think that you are familiar with all the animals that live in ponds— the fish, the newts, and the frogs. But there are any number of pond dwellers that you do not know, for they are much too tiny to be seen by the naked eye. To the right are some of these animals magnified many times.

Photo by American Museum of Natural History

Among the animals of the tiny world to the left are rotifers, fascinating little creatures that, in spite of their smallness, have very complicated organs and extremely queer habits. Leeuwenhoek, whom you will read about on another page, was the first to discover them.

Reading Unit
No. 19

THE WITCHERY OF THE X RAY

Note: For basic information not found on this page, consult the general Index, Vol. 15.

For statistical and current facts, consult the Richards Year Book Index.

Interesting Facts Explained

Rays that we cannot see, 10-492
How Röntgen discovered the X ray, 10-492-93
What a Crookes tube is like, 10-493
What the X ray does for us, 10-493-94
The screen that gives a shadow view of anything the X rays fall on, 10-493
The wave length of the X rays, 10 495
Ultra-violet and infra-red rays, 10 495

Things to Think About

By what lucky accident did Röntgen discover the X ray?
How can we have a moving picture of what goes on inside us?
What kinds of rays are there in the electromagnetic spectrum?
Why did Röntgen make a fluoroscope?

Picture Hunt

What kind of things can we see with the X ray? 10 494-95
What made Röntgen suddenly famous? 10 492

Related Material

What inventions do we have as a result of the study of the flow of electrons through vacuums? 1 514
What would we see if we attended a class in the X ray room? 2-253-54
When did the structure of matter cease to be a mystery? 1 361
What has radium meant to science? 1-283
What kinds of rays fly off from radium, and in what respect are they like X rays? 9-426
What have scientists found in their search for waves shorter than those of light? 1-419
What series of elements is radioactive? 9-425
How are films, including X ray films, developed? 10 450-51

Practical Applications

Why do some art collectors refuse to allow their possessions to be X rayed? 10-493
How does X ray help the doctor and the dentist? 10-493-94

Summary Statement

When Röntgen discovered the X ray, he found something that was not only of very great value in medicine, but that has also been put to more and more uses in science and art as the years have gone by. These rays are too short for us to see them.

Photo by Parke-Davis Co

How should you like to discover something you could not see or hear, and did not even know existed? That is exactly what William Konrad von Rontgen is doing in the picture above. The march of science might have been slower by many years if it had not been for the lucky chance which led to his discovery of X rays.

The WITCHERY *of the* X RAY

How We Found a Kind of Ray that Will Go through Steel and What We Can Do with It

HAVE you ever stopped to wonder why a ray of light will go through glass though not through wood? If you never have, it is only because you have known about it all your life, and so have never seen any wonder in it—even though you know that glass is harder than wood, and denser.

But when you hear about another kind of ray that will go right through wood, and even iron, you begin to wonder. What can it be that will shine through iron?

Well, it is no great mystery any longer. The only trouble is that we are always thinking of any ray at all as a ray of light and nothing else—or of rays and light as the same thing. That is because the rays of light are the only ones that we can ever see. But there are many other kinds of rays besides the ones we see. And one of these will go through a door just as the light will come through a window. It is the X ray.

It was found in 1895 by a German scientist who was looking for something else, but who discovered far more than he was looking for. When he first saw what his unseen new ray would do, he was so far from understanding it that he called it the X ray. For in algebra X is the name of any unknown thing.

Now how could he discover a thing when he could not see it or hear it or feel it? Well, that is a rather interesting story.

He was Wilhelm Konrad von Rontgen (fŏn rŭnt'gĕn), professor of physics in the German university of Wurzburg. Already he had made a name among the scientists, for he was fifty years old. But one morning in 1895 he was suddenly known to everybody in the world who read a paper—for the paper said he had found out how to see clear through a man's body!

He had been experimenting with a Crookes tube near some barium platinocyanide (bā′rĭ-ŭm plăt′ĭ-nō-sī′ȧ-nīd). A Crookes tube is a glass contrivance with the air pumped out and with two wires running into it but not touching. When an electric current jumps from one wire to the other, it makes several bands of light, and Rontgen discovered that when the current struck the second wire, a new kind of ray was sent out from the wire. This new ray was the X ray.

Photo by Metropolitan Museum of Art

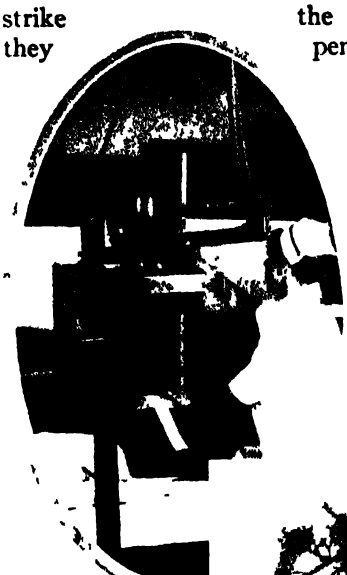
The painting above at the left was thought to have been the work of a certain Flemish artist of the seventeenth century. Then the Fogg Museum took an X-ray photograph of it, which you see in the center, and lo, there was another painting underneath! At the right you may see the original painting after the later one has been scraped off. X ray has proved so useful in making this sort of discovery that some art collectors will not let their possessions be X rayed for fear that what they thought was a great masterpiece may turn out to be a forgery.

Plenty of persons doing the same kind of experiment before must have had X rays flying about them. But how were they to know it? Rontgen found it out by a lucky accident. The barium platinocyanide had begun to glow! Rontgen knew well enough that it was a ray from inside his tube that made the stuff glow. But the tube itself was all covered over with black paper. So there was a ray in that tube that could shine through black paper—and the secret was out.

It is pleasant to say that Rontgen lived to enjoy great honors and to see marvelous things done with the rays he had found. By the time of his death in 1923 the rays were often called Rontgen rays in his honor, just as the tube in which they were discovered had been named for another scientist, Sir William Crookes.

Seeing through Steel

The modern X-ray tube is not a complicated device. It is an electronic tube containing two elements—a hot filament and a metal plate. We have described the action of an electronic tube on other pages of this set. In operation the hot filament is given a negative charge and the plate a positive one. Extremely high voltages are used in X-ray tubes. The voltage between the filament and plate – more correctly referred to as the "target" – may be millions of volts. Electrons leaving the negatively charged hot filament and hastened in their pace by the presence of the highly charged positive plate, arrive at the target at a terrific speed. Under a voltage of 400,000 volts, for example, the speed of the electrons will be close to 155,000 miles a second, or 83 per cent of the speed of light. When millions of these tiny speeding electrons



strike the metal target they penetrate deeply into the atoms of the metals. Dislocations and rearrangements in electrons nearest the nucleus of the atoms result in the release of radiations that we know as X rays.

No hospital could do without its X-ray machines. On the left the nurse is taking the X-ray photograph you see below, which, by those who know their physiology, will be seen to be, not a tangle of weeds, but part of the human body.

What the X Ray Does for Us

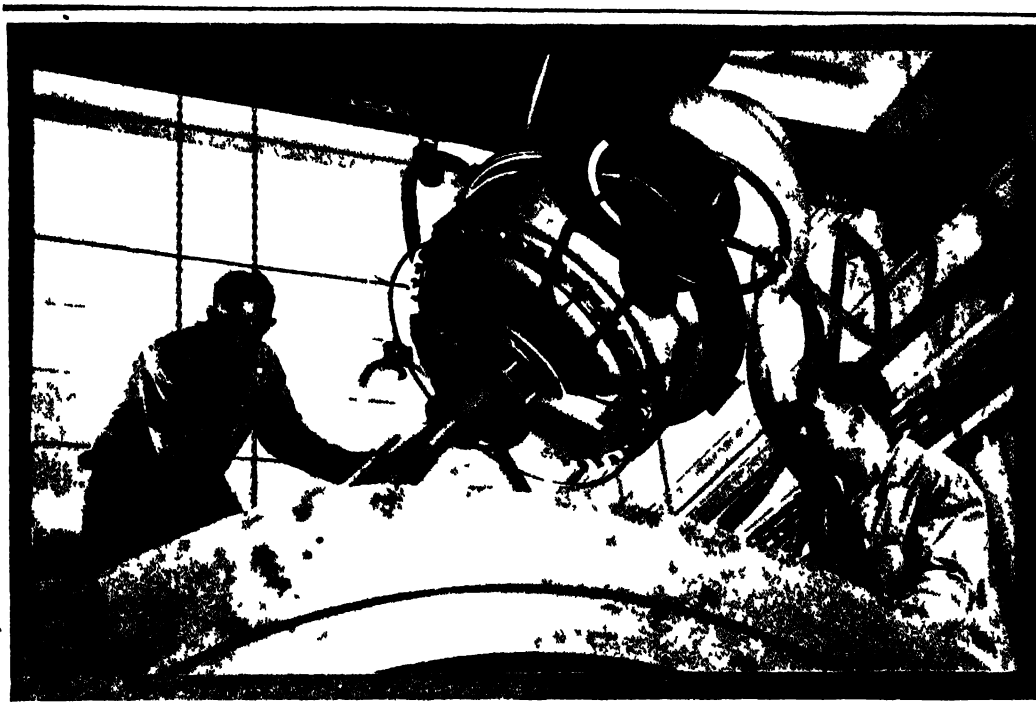
There are few secrets hidden from the doctor nowadays. Before X rays were discovered the doctor had only symptoms and general experience to go by—particularly where the brain was concerned. Now he can see right into any portion of the body he wants to know about.

Of course Röntgen at once saw many of the marvelous things his ray would do. He knew that it would take a picture, for example, without any camera and without uncovering the film, for the rays would go right through the covering. He put a purse on top of a film and took a shadow picture of the coins inside it. And he made a fluoroscope (flōō-ŏr′ō-skōp), or a kind of screen that gives a shadow view of anything the rays fall on. In front of such a screen you can see all the bones in your hand.

And thousands of other men have labored to extend the uses of the X ray. Very soon after its discovery it had been used to find a bullet in a man's leg, and a little later to photograph every bone in the body of a man fully dressed. It is regularly used in setting bones, in order to see how the pieces fit. It will tell whether a man has tuberculosis, whether his heart is pumping as it should, or whether his stomach and intestines are working properly with his food. When the doctor wants a picture of your insides, he gives you a large dose of bismuth (bĭz′-mŭth) to drink first; for bismuth is one of the things, like lead and platinum, which the X ray will not go through so easily, and the outline of your insides shows up clearly against it. So you may have a moving picture of what goes on inside you.

The dentist also uses the X ray very often. No good dentist will touch a suspected tooth until he has taken a picture of it to see what is going on in its roots. Nor will he think he is through filling a root until he has made a photograph to see how the filling fits.

Photos by Battle Creek Sanitarium and William Wood



With entire impartiality and truthfulness this million-volt X ray machine is hunting out hidden flaws in a giant turbine casting It will complete the job in sixteen minutes Weaker machines used to take sixty hours.

The X ray itself has been used in the cure of cancer tumors and other growths In the beginning it was dangerous enough to use and a number of operators were badly burned by it even fatally before they knew it could harm them But it has now been made quite safe if reasonable care is used

Outside of medicine it is used for more and more things as the years go by It can tell you whether a box of chocolates is made of pure materials or whether a steel beam has any weak spot in it It can say whether a golf ball is all it should be whether a locomotive is put together right whether a welding has been well made, and whether a pearl or diamond is real or artificial And it can do many other things It was even used to discover a new chemical element the one we call hafnium

We all know how light that passes through a prism breaks up into different colors that we call the spectrum In the same sort of way the X ray can be passed through a crystal and broken up into what we call a spectrogram (spĕk'trō grăm)

The X rays are a part of what is known as the electromagnetic spectrum, which includes all the rays of every kind All of these rays travel at the same high speed as light but some of them come in long waves and some in short ones

In the middle of this spectrum are the light rays the only ones that we can see. Their waves are 26 millionths of an inch long On one side of these lie the rays of shorter wave length first the ultra violet rays, coming from very hot bodies, then the X rays, and finally the gamma rays, the shortest we have yet found These are more penetrating and more vigorous than the X rays, and their wave length is one ten billionth of an inch

On the other side lie the rays of longer wave length the infra red rays which also come from very hot bodies and the Hertzian waves short and long which are used in wireless The longest Hertzian waves are about seven and a half miles through

So the X ray is only one of a family of rays, all alike in their speed but different in their stride, and all doing marvelous things The ones that make light are as marvelous as any, if we can only pause to think of it a moment, for in all this amazing universe what is more wonderful than simply seeing?

Reading Unit
No. 20

HOW WE MAKE A NEEDLE TALK

Note: For basic information not found on this page, consult the general Index, Vol. 15.

For statistical and current facts, consult the Richards Year Book Index.

Interesting Facts Explained

The first voice signature, 10–498
When Edison invented the phonograph, 10–498
How the voice was captured with wax, 10–498
When music squeaked and rattled, 10–500
What the microphone can do, 10–500
What the record and machinery of the modern phonograph are like, 10–500
How the phonograph can preserve a song for all time, 10–500

Things to Think About

What kinds of disks did Berliner and Edison make?
How did Edison discover the way to make a voice talk again?
Why was it useless to sing a natural song into the old phonograph machine?
How did the development of electronics help to improve the phonograph?

Picture Hunt

What did Edison's first phonograph look like? 10–498
How is music recorded and played on the phonograph? 10–499

Related Material

What is carnauba, and of what use is it? 2–258
How is the light changed back into sound when a talking picture is flashed on the screen? 2–262-64
How does the radio reproduce sound? 10–115, 119, 121
What are some of the amusing devices that make sounds for the radio? 10–119
What produces a high pitch, and what a low one? 1–448-49
What determines the loudness or softness of a sound? 1–449
What accounts for the quality of a sound? 1–450
At what speed does sound travel? 1–446

Leisure-time Activities

PROJECT NO. 1: Make a record of the vibrations of your voice, 10–498

PROJECT NO. 2: Find an old phonograph and play a record on it and on a modern machine.

Photo by Thomas A. Edison Co

This is the great inventor Thomas Edison, looking very tired indeed. And no wonder! For he has just worked five days and nights without stopping on the contrivance you see before him. And he has made it work at last. He has invented the phonograph, which will some day bring music and merriment to countless people.

HOW WE MAKE *a* NEEDLE TALK

The Phonograph Will Carry Our Voices Down through the Ages, Just as the Pen and the Printer Have Kept the Words of Olden Times for Us

NOTHING melts away faster than a sound. One moment we are hearing it, and the next it is gone forever. And many a sweet singer in the years gone by has filled the air with music that vanished on the instant, never to be heard again.

What would we give to hear the famous Jenny Lind sing "Annie Laurie" as she sang it a hundred years ago? Or to listen to Mozart and Beethoven playing their own music? Or to hear Cicero hurling one of his great speeches in the face of the Roman senate? But these things we shall never hear. They are gone the way of all the sounds of long ago.

But our children will be luckier. A hundred years from now, ten thousand years from now, they will hear our great singers and orators of to-day just as clearly as we can hear them now. They will have a vast collection of the words that have been sung and spoken through the ages, just as we have great collections, in our libraries, of the words that have been written. For we now have a machine that will catch the words we speak or sing and keep them for all time.

We cannot see a noise, but we can feel it—if it is violent enough. We have all felt explosions of the kind that make the windows rattle. Of course what we feel is only a vibration, and it takes a loud one to be felt. But we have made a machine that will pick up the very lightest vibrations of a sound and write them down for us; and that ma-

chine will keep a record of anything we trust to it, even of our whispers.

The First Voice Signature

In 1857 an Englishman named Leon Scott grew curious about the way his voice shook and vibrated in his throat, and made up his mind to get a sort of picture of what was going on. He took a piece of sheepskin and drew it tight over one end of a large tube, making a sort of drum. In the middle of the sheepskin he stuck a bit of bristle, with the free end of the bristle resting on a sheet of sooty paper. And the sheet of paper was arranged to turn around slowly as he used it.

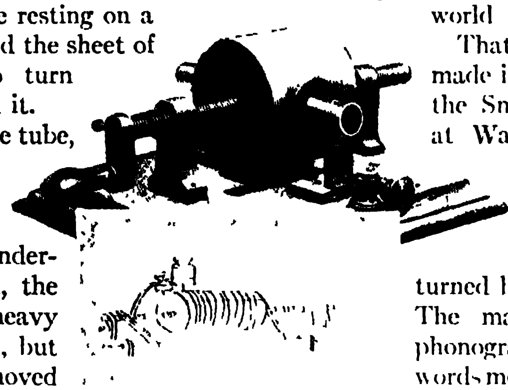


Photo by Thomas A Edison Co

We might guess that the machine in this picture was a toy printing press or a stray bit from a boiler room rather than a phonograph. But a phonograph it is - the first one ever made. By looking closely you can see the grooves in the tin foil cylinder which recorded the sound. It was run by turning the crank at the left. The smaller picture shows the sketch Edison made before he started to work out his great idea.

When he talked into the tube, the sheepskin vibrated and the bristle drew a wavy line on the sooty paper turning around underneath it. If he shouted, the bristle would make heavy scratches back and forth, but if he spoke very low it moved barely enough to leave the lightest traces. When he was through and took the paper out, he had a kind of picture of all he had said. Of course the picture would not say it over for him, but at least it would show how loud and how fast he had been talking.

Leon Scott never went any further than this. He never found out how to make the picture talk back at him That remained for the greatest of all inventors to do, about twenty years later.

The First Machine That Talked

For it was Edison who discovered how to bring back a voice out of the air long after it had ceased to speak, and make it talk again. In place of the sooty paper he used a roll of tin foil, and instead of the bristle he employed a sharp point of steel. He also put a thin diaphragm (dī'ă-frăm) of glass in place of the sheepskin, and a funnel in place of the round tube. When he spoke into the funnel, the steel needle dug a long groove in the tin foil—deep and rough if he spoke loudly, shallow and smooth when he used gentler tones.

Then Edison took out his tin foil and started the needle again at the beginning of the groove it had just made. As it traveled through the groove once more, passing over the deep, rough places and the shallow, smoother ones, it made the glass diaphragm vibrate just about as it had vibrated with the voice in the first place. And then the sound all came back out of the funnel just as it had gone in, word for word. So the world had another wonder.

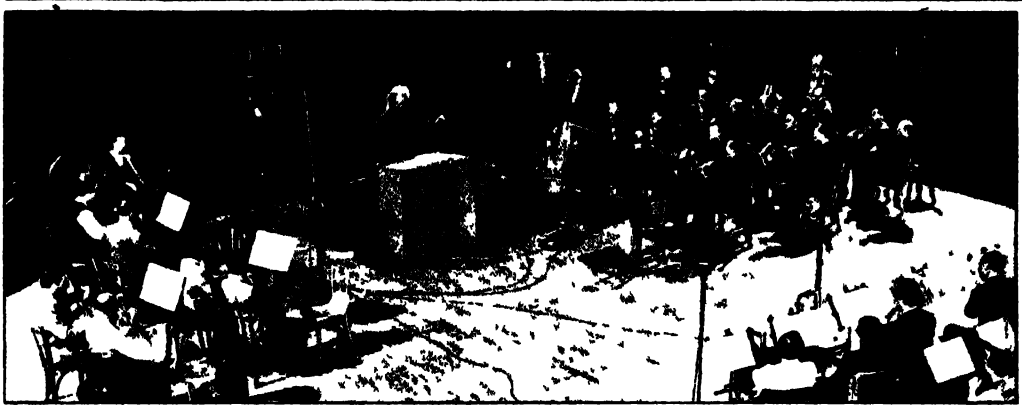
That first talking machine, made in 1876, is still kept in the Smithsonian Institution at Washington. It was a pretty simple affair. It cost only $18 to make, and the tin foil record was turned by hand with a crank The machine was called a phonograph, from two Greek words meaning "sound writer"

The main trouble with the first machine was that the tin foil was so soft as to wear out after it had been used eight or nine times. Of course Edison might well have remedied the fault, but he was busy with a good many other inventions So it was left to other men to perfect the machine and to bring it into wide use

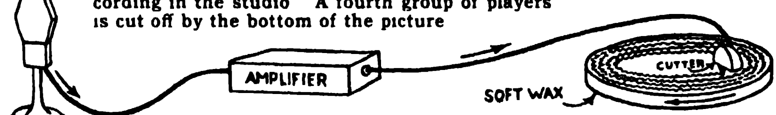
Capturing the Voice with Wax

One of the chief of these was a German named Emile Berliner. He made a good many experiments at taking the record of the voice in wax and in copper, and at last gave us a disk such as we use in our records to-day. When he had a durable disk that could be made in as many copies as were wanted, he was ready, in 1898, to put his machine on sale. And soon many a home had its "music box." It was called a gramophone—which is Greek for "letter sound" —and by that name it is commonly known in Europe to-day.

In the meanwhile Edison had started to improve his first machine, and had perfected



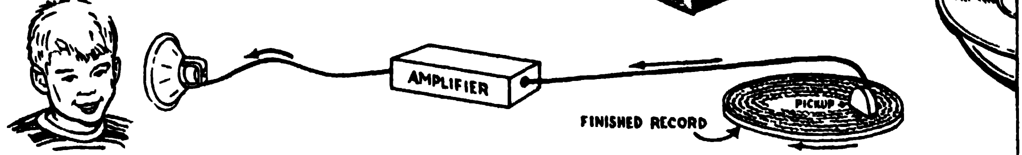
The famous orchestral conductor Leopold Stokowski is leading his orchestra in a phonograph recording in the studio A fourth group of players is cut off by the bottom of the picture



Here we have a diagram of what takes place when sounds are recorded on a phonograph record and then are reproduced when the record is played in a machine Just above at the left a man is speaking into a microphone The sound waves that he creates cause a ribbon in the microphone to vibrate and start electrical impulses flowing Those impulses are fed into an amplifier, which increases their power enormously From the amplifier they go to a device called a cutter It is much like a phonograph pickup and is driven electrically It operates the cutting point This is made of sapphire and rests on a soft wax disk It moves in accordance with electrical impulses fed to it from the amplifier The disk is made to revolve, and as it does so the cutter moves gradually toward the center of the disk, cutting a fine wavy groove around the disk The irregularities in the groove correspond to the variations in the sounds the microphone picked up

When the record is played the pickup needle rides in the wavy groove and so is vibrated from side to side This generates a pulsating voltage that corresponds to the pulsations generated in the microphone The pulsating voltage is amplified and then fed to the loud speaker, which gives us sounds like those in the man's voice

The record cut by the recording needle in the soft wax disk is electroplated Then an impression of it is made in metal That impression or die is used to press the finished records from plastic Some modern disks will play for as long as forty-five minutes



a record made in the form of a tube, or cylinder, instead of a flat disk. For some years the two kinds of records were sold side by side; but finally the cylinders vanished, and the disks alone remained in use—except in the dictating machines that business men use for writing letters.

Music That Squeaked and Rattled

A great deal was left to be done to the talking machine. The first ones on the market were pretty poor affairs. They had to be turned by hand, and they talked through a big tin horn. In time they came to be turned by a spring, and the horn was hidden away in the box. Still worse, the first machines squeaked and chugged so unpleasantly that many a person would not listen to them. But as the years went on they were made to sing and talk smoothly and melodiously. Among the many improvements, the greatest of all came as late as 1925.

For then the new-found radio began to do great things for the old phonograph. Before then it had been impossible to sing a natural song into the machine. The singer had to bellow into the big horn to make the record, and the record was always more or less strained and distorted. An orchestra or band had to be crowded together right around the horn; and many pieces had to be left out because they could not get near enough, or special pieces invented for the service of the big horn. So the record was a bit different from the music that would have been sung or played on any natural occasion.

The Magic of the Microphone

But since the radio came, the singers have sung and the orchestras have played before a microphone. Here they can make their music just as they would offer it to an audience. For the microphone will pick up all their lightest tones, and the sound will be carried through a vacuum tube—one that is empty even of air—before it is cut into wax and made into a record that will give back just what has been heard. Even outdoor music can be caught and written down in this way.

To-day our phonograph is not so simple as it used to be. The record looks about the same—a flat disk of hard black shellac or of molded plastic. In a spiral on its face is the groove called a micro-groove if it is very tiny. The machinery is about the same —a little platform for the record to turn on, with a spring or an electric motor to do the turning. The needle may be of various kinds. It may be of steel or various types of alloys, or of sapphire. But the sound box and the horn are different, for electricity has come to regulate the sounds and make them natural and clear. That all came with the development of electronics, one of the miracles of our century.

A Boon to Civilization

For a long time most lovers of music made loud fun of the phonograph And they might well do so, for it was a pretty poor and harsh contrivance. But the horrible scratches and kerchunks were soon done away with; and now we may have the sweetest music from great singers and orchestras that may never come within a thousand miles of many of our homes. Just as printing has scattered books far and wide over the world, the phonograph has carried speeches and songs to the ends of the earth. Before the radio came, the phonograph was so popular that a great singer might earn as much as $100,000 a year lending his voice to it.

And even since the radio, the phonograph alone can hold and preserve a speech or song for all time. It will carry the great songs and orations of our day down through the centuries to the children of our children's children. Thousands of years from now they may be listening to the accents of men who have long been silent. How much easier it will be to learn an ancient language! And many a noble word out of the past will fall upon their ears exactly as it was first uttered by some famous man who will fill so many pages in their books of history.

Reading Unit No. 21

PICTURES TO MOVE AND TALK AND TELL A STORY

Note: For basic information not found on this page, consult the general Index, Vol. 15.

For statistical and current facts, consult the Richards Year Book Index.

Interesting Facts Explained

When the first moving-picture show was given, 10 502

How Edison took pictures on a film, 10 503

When movies were first thrown on a screen, 10 503

How sound is changed into light and then photographed on the film, 10-504

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Practical Applications

What makes it possible for us to see in a moving picture exactly what a diver does? 10 512

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Leisure-time Activities

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PROJECT NO. 2: Draw an animated cartoon on the successive pages of a notebook.

Summary Statement

With the use of the film in the camera it has become possible to take a long series of photographs so fast that the eye will not notice the gaps between them and will therefore seem to see the things moving which is all that is needed for the moving picture.

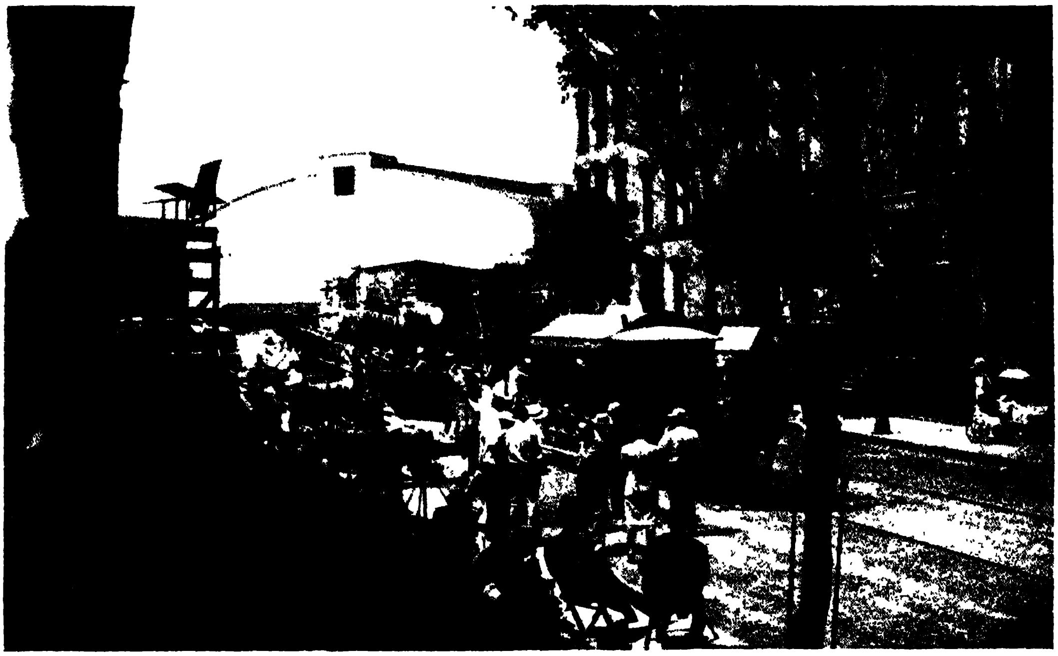


Photo courtesy of Warner Brothers

This scene from "Life with Father" is being filmed in an imitation street put up on the "lot" of a moving picture company. Those brown stone fronts are permanent but there are no houses behind them.

PICTURES *to* MOVE *and* TALK *and* TELL *a* STORY

About the Great New Art of the Twentieth Century

IF YOU had been living in New York in 1894, you could have gone to a certain house on Broadway and seen the first real moving-picture show. The house was not a theater, of course, and you would not have sat down in a chair to look at a screen. You would have had to squint through the eyepiece of a little machine while you turned a crank to make the picture move inside it. The machine was a kinetoscope (kĭ-nĕt′ō-skōp), and it was the humble parent of all our many motion pictures of to-day.

Even earlier there had been a good many persons in different countries trying to make pictures of things moving. Before we found out how to make a photograph, we began to wonder whether we could manage to make a picture move—to make it show a man walking across a room or running down the street; in 1824 Roget, in England, read a paper bearing on the subject.

All over Europe people began experimenting. It was not long until J. A. Plateau, of the University of Ghent, and an Austrian named von Stampfer had discovered, at about the same time, a way to show a rapid series of pictures of an object in motion. They both did it by mounting the pictures in order around the rim of a disk and then whirling the disk. Of course their pictures were drawings, not photographs. By 1853 another Austrian named Uchatius had discovered a way to combine the disk with the magic lantern. This put a light behind the disk, and in that way the pictures could be thrown on a screen.

It was Coleman Sellers, a Philadelphia engineer, who seems to have first used photographs instead of drawings to show his moving object. In 1860 he took a number of pictures of his little boy driving a nail with a hammer. In the first picture the hammer was up in the air, in the next a little lower, in the next a little lower still, and so on until it was striking the nail. Then Sellers made a paddle wheel with many blades, and put

one picture on each blade. When he spun the wheel fast, one picture followed another and showed the boy hammering the nail.

It was an interesting trick, but nobody dreamed of doing much more with it.

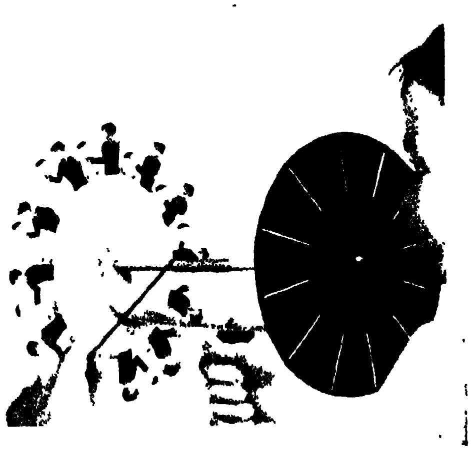
The First "Movie" Camera

Out in California, about ten years later, Leland Stanford wanted a picture of a race horse in action. He gave the problem to an engineer named Isaacs; and the engineer worked out a scheme for putting a great many separate cameras along the track, under electric control, and so snapping the horse in all his positions as he passed. But there were still large gaps between the views.

Of course we could not manage enough cameras to make a reel of a few thousand pictures. So we had to find a way to make one camera take them all, and very rapidly. And we could not do this until Eastman gave us a celluloid film in place of the old glass plates on which separate pictures had been made before.

Then, in 1889, Edison wound a strip of film on a reel and managed to snap a quick series of pictures in a special kind of camera as the film unrolled. The camera he made was very much like the ones in use to-day. The narrow strip of film unrolled behind a shutter that opened and closed forty-eight times a second. When it opened, the film stopped still and took a picture; when it closed, the film moved on into place for the next picture. That is the way a moving-picture camera works now.

So the moving picture is easy to understand. All we need for it is a long series of photographs taken so fast that the eye will not notice the gaps between them and will therefore seem to see the things moving. Now for a sixteenth of a second the eye will hold any image it has just seen; and in that brief moment one picture may go off and another come on, without our ever knowing it. All we seem to see is something moving on the screen. We can, however, take as many as 5,000,000 pictures in a second.



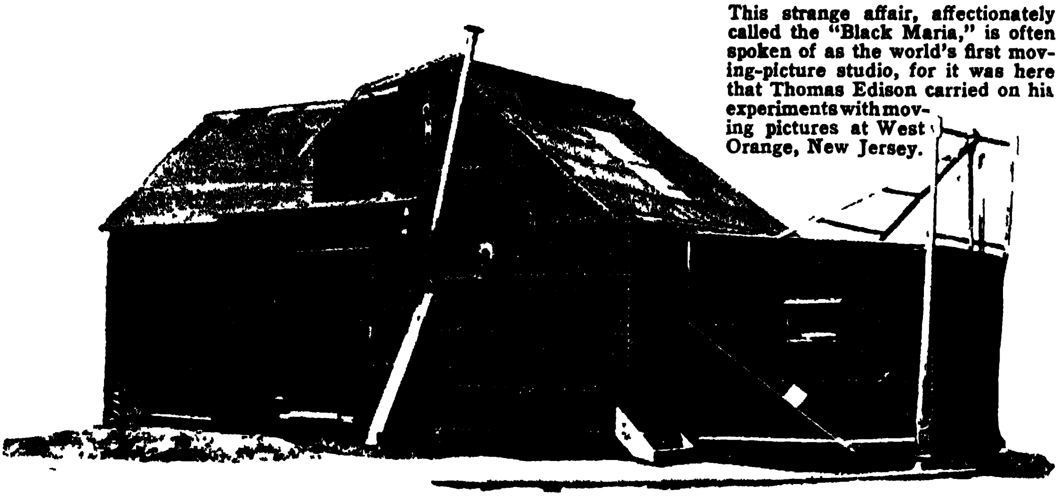
This is the earliest ancestor of the "movies." Of course the pictures one saw through the little slits in the black disk were drawings, not photographs. And one looked at the pictures themselves, instead of at the shadows they threw on a screen. But when the cord was pulled and the two disks whirled, the boy painted so many times on the white disk seemed to be driving a nail with his hammer. If it had not been for the dark disk, with its little slits, the pictures on the white disk would have been only a blur when the disk was whirled.

When we have once taken a picture and developed it, we can make any number of copies. And since the film is transparent, we can flash a light through it and throw it on a screen for all to see. But curiously enough, that is something that never dawned on the great Edison. He made only the little kinetoscope, with a peephole for a single person at a time to watch the show inside.

But many other men began to work on the invention. Two French brothers named Lumière (lü'mē'âr') perfected it and developed a machine called a projector to throw the image on the screen—magnified some thirty-five thousand times. The Lumières used to take sixteen pictures in a second and for each foot of film. For the talking picture of to-day we take twenty-four a second.

Of course the early pictures seem pretty jumpy and awkward to us now. For in the short time since their invention we have brought the camera and the projector to a high state of perfection. We can even show pictures in colors. And finally we have made the screen talk! Until 1928 the "movies" were always quiet; they used to be called the "silent drama." Now there is as much talk as in any other theater.

The machinery for talking was not invented by any one man. It was made by many people working in an electrical plant.



This strange affair, affectionately called the "Black Maria," is often spoken of as the world's first moving-picture studio, for it was here that Thomas Edison carried on his experiments with moving pictures at West Orange, New Jersey.

Photo by Thos. A. Edison Co.

It combines the features of the phonograph and of the radio.

When the actors speak, the sound may be taken up by a microphone. Now a microphone will catch every sort of sound around it, and if we want it to get nothing but the actor's voice, we must keep out every other sort of noise. So from being a very noisy place indeed, the moving-picture studio has suddenly become about the quietest on earth. It is hung with heavy curtains to deaden every echo, and the cameras are placed in padded booths. No one must go in or out while the work is under way.

As the player speaks, the little instrument picks up his voice, and electricity carries the sound to a phonograph record that is being made along with the pictures. With the help of vacuum tubes, as in the radio, the sound may be increased or softened to secure the best effect.

Changing Sound into Light

The camera and the phonograph record have to run at exactly the same speed, or else the picture will not match the voice. It will not "synchronize" (sĭng'krô-nīz); and then we might hear the voice before we saw the lips move. So the electric motors that operate the cameras and the phonographs must work perfectly together.

There is still another way of recording the sound—on the film itself instead of on a phonograph record. By a remarkable invention, the sound is simply changed into light and then photographed on the film. The electric current from the microphone is made to work upon a glowing lamp. When the sound is loud, the lamp is bright, and when softer the lamp is dimmer. And then the light is photographed in a narrow streak down the edge of the film, by the side of the pictures.

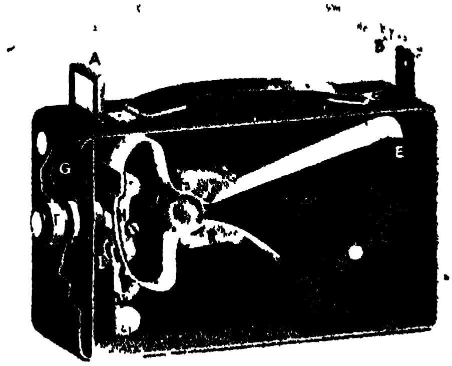
Getting Sound from Celluloid

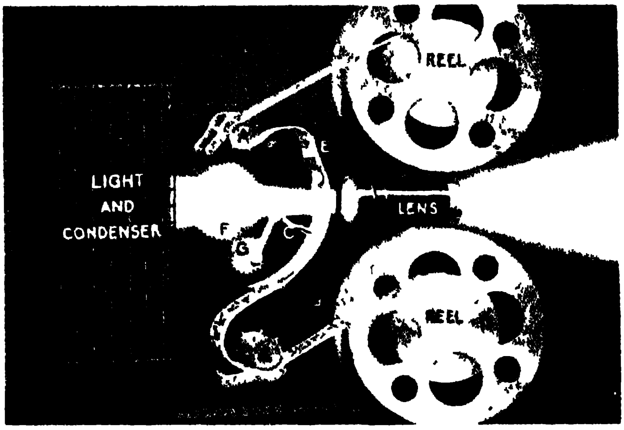
When the picture is flashed on the screen, the light is changed back into sound again. A ray of light shining through the narrow streak gives the same glow as the original lamp; and when this is taken up by the photo-electric cell, an electric current is developed that operates a loud speaker on the stage of the theater.

But now we are far ahead of our story. We have gone on telling how all the machines were perfected, and we have not said what was being done with them. So we must go back again and say what sort of plays were made.

In the beginning there was no play at all. The moving picture was only a toy, and not a very popular toy at that. The writer of these words well remembers a good vaudeville theater in New York some half-century ago which gave a continuous performance from one o'clock to eleven. For fifty cents a man could sit right through the whole performance, if he liked, and see all the acts

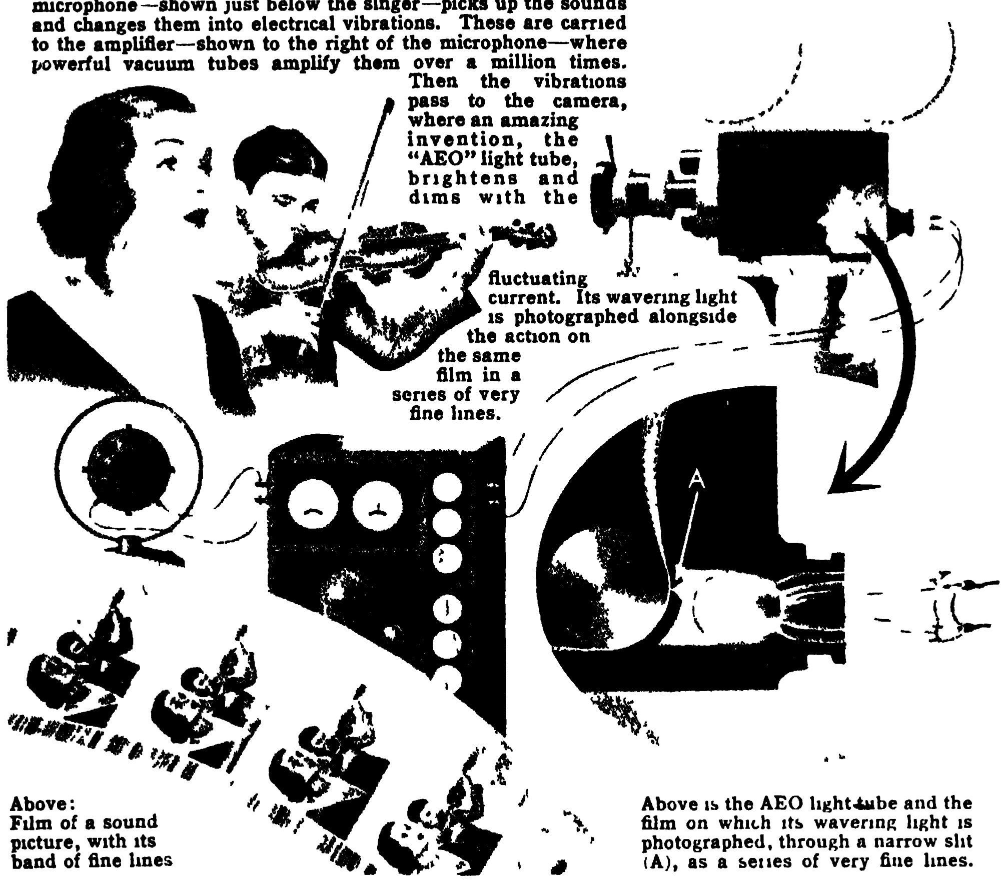
In the oval is the inside of a moving picture camera. The person taking a picture looks through the hole at B and sees in the "finder," A, the object to be photographed. Then he presses a button and sets the mechanism working. The round shutter at G begins to revolve, like an electric fan, and every time the hole in it comes into position behind the lens F, light passing through the lens strikes a little square of exposed film at the bright spot marked H, and a picture is taken. As the shutter revolves, the light is shut out again, and while it is shut out, the two little claws at I seize the film through a pair of little holes in its edges, and pull the film down just far enough so that a fresh, unexposed square of film--or "frame," as it is called- is brought into position behind the lens. Then, when the shutter has revolved far enough to bring the hole in it behind the lens once more, another picture is taken on the fresh frame. And so the process goes on. The unexposed film is wound, to start with, around the reel at E, and the little cogwheel at C, in the center of the camera, pulls it off the reel by fitting its cogs into the pairs of holes along the edges of the film. At the same time this little wheel passes the film that has been exposed at H to the reel at D, where the exposed film is wound up. The pieces J and K serve to hold the film against the cogwheel, so that the cogs may fit into the holes. The claws at I have to work by jerks, for they must pull the film past H by stops and starts. They give the film sixteen jerks a second; that is, sixteen pictures a second are taken on the film.





At the right is a projector which sends a powerful ray of light through the pictures on a moving-picture film, and focuses the ray on a screen in such a way that the shadows cast by the film may be clear and sharp. The machine is run by electricity, which furnishes the light and operates a motor out of sight in this picture to drive the mechanism for passing the film in front of the light. The oblong wire cage at the left contains the "lamp house," in which is an electric lamp to furnish the light and a lens for condensing the rays. These are concentrated on the projecting lens, which is in the little cylinder at the right. Between the lens and the lamp is a curved strip of metal, D, with a hole in it just in front of the lens. This strip of metal is known as the "gate." As the long strip of film, with its series of pictures, is passed over the gate, each picture stops for a brief instant in front of the hole. This allows the light to pass through it and fall upon the lens. Then, as the film passes down over the gate, another picture comes between the lens and the light, and another set of images is cast on the screen. And so they follow, in swift succession. In order that the shadows on the screen may not be blurred as the film passes rapidly in front of the light, there is a revolving shutter, E, which consists of a disk with holes in it. Whenever the film is being moved, this shutter, which passes between the lens and the film, shuts off the light from the lens; but as soon as a picture on the film comes squarely in front of the lens, the hole in the shutter has come into a position to let the light through for just an instant.

A neat mechanism keeps the film passing at even intervals over the gate. It consists, first, of two little cogwheels at A and B. The cogs in A fit into holes along the edges of the film, and as the wheel turns, it slowly unwinds the film that is wound on the upper reel. This film passes down over the gate, and then is fed to the lower reel in the same way by the wheel at B. A little pronged lever, operated by the wheels F and G, fits into the holes in the sides of the film and jerks the film, a picture at a time, down past the hole in the gate. This little lever must work very fast. It has to grab the film sixteen times a second, jerk it down, let go, and then grab it again.



When sound pictures are made, a moving-picture camera - shown here at the right takes a picture of the action, and a microphone—shown just below the singer—picks up the sounds and changes them into electrical vibrations. These are carried to the amplifier—shown to the right of the microphone—where powerful vacuum tubes amplify them over a million times. Then the vibrations pass to the camera, where an amazing invention, the "AEO" light tube, brightens and dims with the fluctuating current. Its wavering light is photographed alongside the action on the same film in a series of very fine lines.

Above: Film of a sound picture, with its band of fine lines

Above is the AEO light-tube and the film on which its wavering light is photographed, through a narrow slit (A), as a series of very fine lines.

twice. But the managers had a way of clearing the house. About six o'clock they put on a moving picture. It lasted only about ten minutes. But it was so tame that nearly all the people would get up and go out.

And well they might. For the moving picture of that day had little to show except a few stale tricks and curiosities It reached its very peak when it managed to show half the people in a village chasing some comical fellow through the streets and possibly falling into the river at the end Nearly every picture closed in some such chase, and the people in the theater were simply bored by it.

From Comics to Classics

But in 1903 a real story was told in a picture called "The Life of an American Fireman," and this was followed by "The Great Train Robbery" Of course these little plays were packed with thrills, and for a long time the moving pictures were going to show very little except feats of daring and danger—Wild West scenes and cowboy adventures. But these were at least plays, however poor. And by 1905, in Pittsburgh, the first theater was opened to show moving pictures only.

The early plays were one reel long—a thousand feet of film—and for a good while this was the standard length of moving pictures. It was a great event when Adolph Zukor began to bring out plays in two and three reels. And to such directors as Zukor and D. W. Griffith we mainly owe the amazing growth of the photoplay of our times.

Photo courtesy of Warner Brothers

Two film stars are about to be "shot" in this handsome ballroom built in the studio. The hero is in his stocking feet in order to look shorter. The camera will not show them when the scene is filmed.

For the photoplay is a child of our own century.

By 1907 we had "Ben Hur" on the screen, and by 1913 "Quo Vadis." These were grand spectacles in their time. In 1912 Zukor scored a triumph by persuading the great French actress Sarah Bernhardt to play in a moving picture—for at the start the well-known actors were very scornful of the "movies." By 1914 Griffith gave us, in "The Birth of a Nation," a play that made an era in the art and drew thousands of spectators who had never gone to picture plays before.

What the Movies Gave the World

From that time the picture play has gone on steadily and rapidly to the perfection it enjoys to-day. It has told stories that are longer and very much better. It has shown more and more marvelous scenes and settings. It has drawn in the greatest actors and actresses in the world—many from the regular stage, and many who have never acted anywhere except before a camera. It has done wonders in a new kind of acting—for never before in the world had actors known how to say so much with their faces and their gestures, with the curl of a lip, the shrug of a shoulder, the glint of an eye. And it has spent money in enormous sums; for in these few years the photoplay has grown into a vast business enterprise. It is now amusing a hundred times as many people as were ever amused by any one thing in the history of the world before. The industry, centered in Hollywood, California, sends films all over the world.

If we have a story that we want to put on the screen, how do we go to work? It is one thing to write out the story for a book or magazine, and a very different thing to put it into pictures—so different that very few men can do both.

First we divide the story up into various scenes. In the regular theater there would usually be three or four of these, for the properties on the stage cannot be changed much. But in a photoplay there may be hundreds of scenes, for we may alter them as often as we like. So in this way the moving picture can do far more than the regular stage could ever dream of doing. And the first thing to do will be to make out a long list of scenes and of the action in each one. That is the "scenario."

But the scenes may be in very different places—some in California and some on

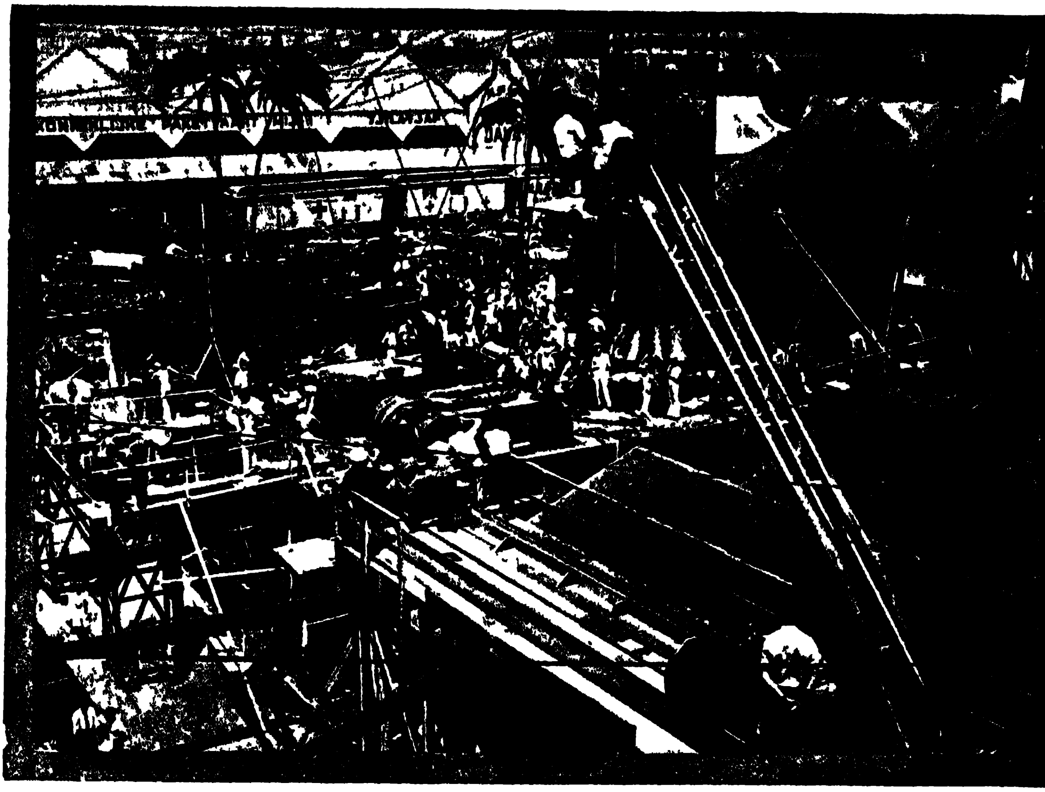
Broadway, some on an ocean liner and some in Baghdad, with others in many other spots. Clearly we want to take all the pictures for each place—or "location"—at one time. We do not start the first scene in California, go to Baghdad for the second, and return to Broadway for the third. Instead we must take all the California scenes at once, wherever they may finally come in the picture, then all the Baghdad scenes, the Broadway scenes, and so on for the rest. Our scenario must therefore be cut up into various sets of scenes for the various locations. It is then a "continuity."

At this point it goes to the director. He is a most important man. You may not see him in the picture, but his hand is in it everywhere. He plans the whole play, and by heroic effort sees that every person in it does exactly the right thing at the right time. He alone knows what the whole picture has to do; and in any given part he may be forcing an actor through an exquisite bit of a scene—of sorrow for the death of a sweetheart or of joy in the discovery of a gold mine—when the actor has not the slightest notion what it is all about or what the whole play will be like.

Before the actors begin, the scenery must be ready. In many plays the most extraordinary scenes must be shown—courts and palaces, deserts and dungeons, ice huts and medieval castles and Roman arenas. So every big studio must have its architects and artists as well as its costumers, and they are often called upon for the most marvelous feats of art. Sometimes a whole city has to be built for a single film. A big studio may keep ten thousand costumes in stock, and then have many made to order as required for a given play. And of course the cost is enormous. It may well take a

It is not always easy for a moving-picture actor to get just the right expression. The greatest actor may fail at this. So producers have thought up ways to help the performer by action just out of range of the camera. Above, you will see a man looking quite as much startled at the thought of being hit in the eye with a bean shooter as he would look if he had just been told that the police were on his trail. And at the right, a number of gentlemen in threatening attitude are helping the hero to find the expression he should wear when waiting for the villain to come on.

Photos by Paramount and First National Studio



The scene at the back of the picture is being "shot" in this moving-picture studio. Can you find the camera?

million dollars to put a picture on the screen.

While the scenery is being made, the actors will be chosen. There are stars in every studio, of course, but often hundreds and even thousands of extra people must be found for a given play—soldiers, Indians, cowboys, mobs, and what not. A play like "The Covered Wagon" uses some three thousand "extras." The extras can hardly get rich, but the stars are paid enormous sums. The best of them earn salaries larger than are paid to any other person in the world except a few crowned heads.

When all is ready, the filming begins. Then a number of other experts come into action. A large studio may employ as many as forty cameramen, twenty or more property men, a few dozen chauffeurs and truckmen, and a hundred or more electricians; and all of these may be busy at once when the "shooting" starts. The lighting of the scenes is a fine art all by itself.

Over all the army of workers the director reigns supreme. The players in particular obey his every word and gesture. They must be very highly trained in make-up, for the camera plays strange tricks with colors. Anything red will look black on the screen, and anything yellow will be white. So if you want your cheeks pink in the picture and your hair yellow, you must have them some other color when you stand in front of the camera. In the studios we often see actors and actresses with their faces greenish and purple. They will look all the better on the screen.

The players must be even more highly trained in acting. It is no easy trick to keep in the right place before the camera, no matter how much you have to move around, and to have your picture taken thousands of times without ever looking at the machine or ever seeming to know it is there. Have you ever tried to look "natural" in the face of a camera? And it is far harder still to make your features tell all the intense emo-

tions you are supposed to feel as the play goes on. That would be hard enough in the quiet of the studio; but often it must be done in a blistering desert or on an icy mountain peak, in a howling mob or a blazing building. Even in the studio the glare of the powerful lights will ruin the looks of anybody but an actor of long training.

For these and other reasons, the very best actors often have to go through a scene time and time again before it is perfect for the camera. And even then it is likely to be too long. So when the whole film goes to the editorial department of the studio, it is likely to be cut and pieced in many places before it is ready to go out over the world.

In the various studios a whole new language has been born. It is only slang, of course, and is often more forcible than beautiful. But there is so much of it that a stranger is often at a loss to know what the people in the studio are talking about.

To "crack the sun" is to turn on the big arc lamp. "The Charlie has the bloops" means that the actor with a mustache has a deep, resounding voice. "I've been pulling a horse opera" means that I have been working on a cowboy picture. "What a lamp post!" means "What a gorgeous piece of jewelry."

And so on with hundreds of other words and phrases. A language of this kind always grows up when a great many people in high spirits live and work together—as among the boys in a college.

In one sense the camera always tells the truth. It shows exactly what it sees. But we can still make it do a thousand tricks that will look like anything but the truth.

Photo courtesy of Flaherty Films

From "Louisiana Story" comes this shot of its young hero photographed "on location." Many of the scenes in the play are laid on the rivers and bayous of Louisiana. Many of them, too, are documentary, and show the people living there as they go about their work. Here the hero is making his way through the reeds that grow in the marshes.

In the early days of the moving picture, it was a favorite trick to show a man diving off a springboard into the water, and then coming back up out of the water feet first, floating in a graceful curve up through the air, and landing on the springboard where he started. Of course, the picture was just run through the projector backward.

But suppose we want to show a great train plunging over a bridge into a river. No railway is going to lend us a bridge and a train to wreck, and it will be very costly to bui'd one for ourselves. So we just make a tiny bridge and train, exactly like the big ones. Then we wreck it in the studio and take the picture; and when we magnify this on the screen, nobody in the world will know the difference

In the same way we can wreck a steamboat on a table in the studio Then we can take some pictures of the ocean, and put the two sets of pictures together to show the ship sinking in the sea.

Sometimes a single actor appears as two different persons in the same picture—one to the right on the screen, the other to the left. In this case two pictures have been made and pieced together. If you have ever seen an angry lion plunging at a frightened heroine on the screen, you may be pretty sure he was really jumping for a piece of raw meat. In one picture twenty lions were turned loose on a group of Christian martyrs. But the front rank of the martyrs were all lion tamers, though they kept their whips and pistols out of sight. As the lions plunged,

Photo by Fox Movietone

This is a picture of what happened every day at noon in the desert city especially constructed to house a moving-picture company. They were acting in a production photographed near Zion National Park, in Utah. Often "mountains" and "deserts" can be set up in the studio, but if a whole drama with a great deal of scattered action, such as a "Wild West" play, is to be filmed, it is necessary to convey the company and equipment to some likely spot. There they work very hard until the photographs are all taken. It is exacting and wearying toil for actors and camera men, and for everyone else concerned in the production.

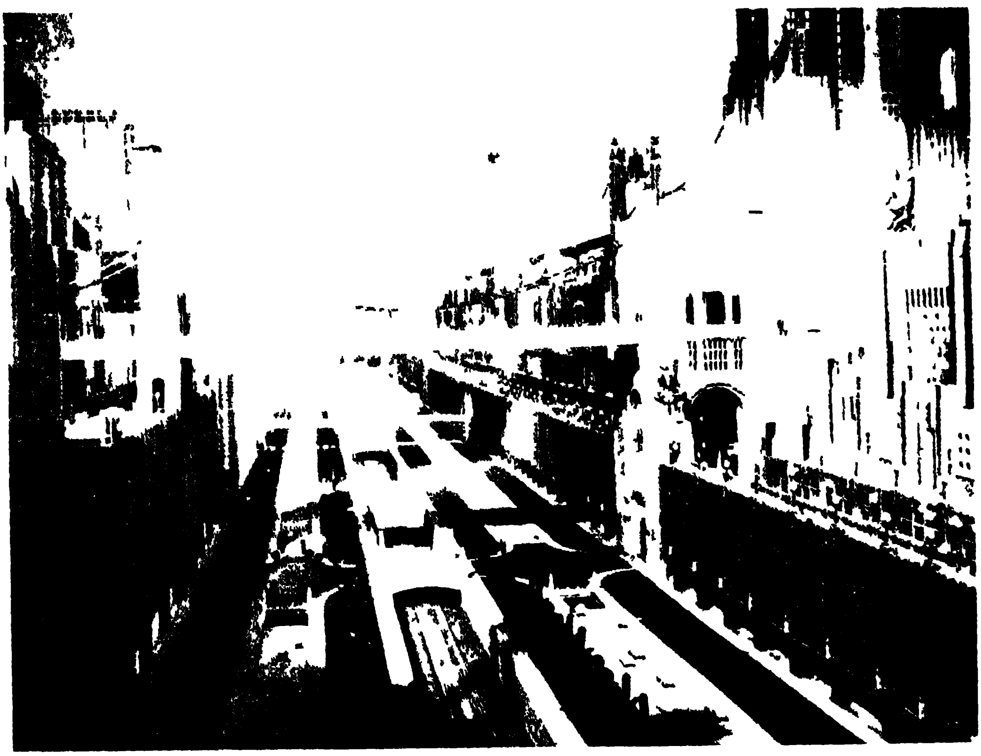


Photo by Fox Movietone

When a really beautiful production is to be filmed, no expense is spared. Those are not cheap costumes you see in a good film, nor is the antique furniture made in the studio. Everything is genuine. Talented artists and interior decorators design the settings, and the greatest pains are taken to have the least detail perfect. The scene above is a picture of a model made in the studio for use in a film called "Just Imagine." It is supposed to be a picture of the New York of 1980. Now of course the New York of 1980 could hardly be shown "true to life," but many months were spent in making this model perfect architecturally.

the cameras stopped and the tamers drove the beasts back to their dens. Then some dummy bodies were soaked in bullocks' blood, and the cameras were started again to show the lions tearing at them.

We have all seen a man on the screen run over by a steam roller, only to get up and walk merrily away. Of course the camera stopped just before the roller hit him. Then a dummy was put in his place to be run over. And then the camera stopped again while the man took the dummy's place. When it started once more, the man was getting up and running off.

Photo courtesy of Warner Brothers

In the foreground is the forbidding array of apparatus and technical skill that was necessary to make this peaceful scene look real on the screen. The microphone is overhead on the end of the boom.

Wonders the Camera Shows Us

Finally, the camera can show us a great many things that we could never see without it. In many ways it is the best teacher we can have.

It is the only thing to show us the wonders of motion. There is a special camera to take pictures as fast as fifteen hundred a second. When these are put on the screen at twenty-four a second, we see an extraordinary slow motion that shows how everything was done, to the smallest detail. So we can see exactly what a beautiful diver does as we watch him floating slowly through the air. In the same way we can watch a bounding tennis player or a plunging horse or even a whizzing bullet.

For things that move very slowly we can do just the opposite. We can make a snail dart about like a lizard. We can take pictures of a growing plant, one every few hours. When we run these off rapidly on the screen, we may see the whole plant sprouting, growing, budding, flowering, and dying, all in a few minutes. We have beautiful pictures of spiders weaving their webs, of ants busy at their work, of grasshoppers "singing," and of many other marvelous things in nature. There is a great deal of education in the screen.

Teachers have seen that this is true, and whenever they can they bring motion pictures into the classroom. History, geography, English, science—in all these subjects vivid and interesting films help the textbooks and prove to the student that "seeing is believing"—and remembering as well. The last World War taught us that films can be of great use in teaching various skills – in industry, for instance, or in military science. And many a distant village learned from the "movies" that people of quite another race or color were working day and night to help bring victory to the cause for which we all were fighting. Those lessons were not forgotten when the war was over. To-day in-

structional films are shown wherever people want to learn - in schools, factories, churches, and training camps. We even have them in the home.

In other ways, too, the "movies" helped to bring us victory. They went to war all over the world and in many guises. There were the newsreels as a record of history, the training films, combat bulletins, and information films for both fighter and civilian. The motion-picture industry sent out 6,810 artists to entertain the armed forces both at home and abroad. Every day, while the war was at its height, our fighting men saw an average of 3,500 moving-picture showings—gifts from the motion-picture studios.

What Is a "Documentary"?

The war also saw the full flowering of what we call the "documentary" film the picture that is an unvarnished, factual record of man's struggle with the physical world around him. The first film of this kind had been released in 1922 "Nanook of the North," it was called. There people saw a faithful picture of life in the cold North – recorded on the spot. More and more such films were produced in the years that followed, and always the public gave them a hearty welcome. So it was not strange that during the war the camera was set to work recording the horrors and the heroism of that gigantic struggle. The result was magnificent. No one who saw them will ever forget pictures like "Desert Victory," "The True Glory," or "The Fighting Lady."

Our Newest Art Form

The motion picture, once despised by the "highbrow," has also had the honor of bringing us our newest art form -and an art form is not originated every day. It all began when a boy from a Missouri farm began to draw pictures of the farm animals on the margins of the pages of his schoolbooks. He was clever enough to arrange the sketches in such a way that when he turned the pages rapidly the animals seemed to move. You probably have already guessed that that boy was Walt Disney (1901–), and that the new art form was the animated cartoon.

Like many another man who came to fame Walt Disney had to make his way alone, with very little help from Fortune. He was born in Chicago, the son of a contractor, but his boyhood was spent in Missouri—first on a farm and then in Kansas City. His first commercial success came when, at the age of ten or eleven, he got a free haircut for drawing a sketch to adorn the wall of the town barber shop. After he went to live in Kansas City he delivered papers after school, and later, when he was in high school, he worked on a train selling papers, magazines, peanuts, and candy. By the time he was sixteen he had earned enough money to pay for a night course in cartooning at the Academy of Fine Arts in Chicago. Those few months of evening study were about all the formal art training he ever had.

When the United States entered World War I the boy was too young for the Army, but he managed to see active service overseas as an ambulance driver. Back home, he got a job as illustrator on a farm journal in Kansas City and in his free hours began drawing cartoons for a film company.

Disney Goes to Hollywood

It was in 1923 that he finally went out to Hollywood to join a brother who was already employed there. His sole capital at that time was forty dollars and a print of a cartoon called "Alice in Cartoonland." The two young men formed a partnership, and after three months of discouraging search a producer was found for the cartoon. For the next four years Disney gave all his energies to making cartoons of Oswald the Rabbit. At the end of that time he and his brother set up their own company and Walt produced the first great creation of his gifted imagination —the immortal Mickey Mouse. The third Mickey Mouse film was provided with a sound track, and Disney himself spoke Mickey's lines. The film was an enormous success, and Mickey's creator came into lasting fame.

The Followers of Mickey Mouse

The graceful wit and delicate fancy that had produced the gallant Mickey now gave birth to a menagerieful of delightful animals. Donald Duck, Pluto, Minnie Mouse, and

Goofy began to troop across the screen and to delight audiences in every land on the globe

The Mickey Mouse films and the Silly Symphonies were shorts as was "The Three Little Pigs" (1933), the first film of Disney's to make an individual reputation But though for four years he was awarded the annual prize of the Academy of Motion Picture Arts and Sciences Disney was not satisfied He borrowed money from the bank and, against the advice of the whole motion picture industry, started on a feature length film He called it "Snow White and the Seven Dwarfs" but people in Hollywood called it "Disney's folly" For the film, on which he spent three years cost $1 600 000 and had to take in $3 500 000 before it could return a dollar to its creator When the exquisite fairy tale was released (1937) its receipts mounted to $8 000 000 in only a few months

"Fantasia"

A year later Disney repeated its success with "Pinocchio" and in 1940 he carried his new art form still farther with "Fantasia" in which, by an entirely new method of recording, he set his pictures to a number of famous musical compositions

How Animated Cartoons Are Made

Walt Disney produces his pictures in a little 51 acre city all his own, where the work of his thousand or more employees fills twenty different buildings He no longer draws his own cartoons, but he still oversees every least detail First the action is carefully mapped out and the musical score is roughly timed to fit the sketches Then the artists—called the "animators"—set to work drawing by hand the thousands of scenes that will fill the reels Senior animators first sketch all the important points in the action and establish the characters of the actors Then the routine workers fill in the steps between The whole is photographed and criticized by Disney himself before the scenes are inked in and painted in color The process is slow and very difficult For the sketches cannot be just pictures The figures must live

Disney says he never has planned his pictures for children only Perhaps that is why children like them so much

Walt Disney is at work at his drawing board, sketching a sequence in which his famous Mickey Mouse will appear When Mr Disney has finished his part of the work other artists will fill in events and details

Reading Unit
No. 22

ALL THE WAYS OF FREEZING THINGS

Note: For basic information not found on this page, consult the general Index, Vol. 15.

For statistical and current facts, consult the Richards Year Book Index.

Interesting Facts Explained

When the first blocks of ice were cut and stored in America, 10 515
How ice was kept from melting, 10-515
Why we light a fire to make ice, 10-515
When the first refrigerator car was built, 10-518
How storage rooms on big boats are kept cold, 10 518
How care is taken to keep out the heat in cold-storage rooms, 10-518
How our refrigerators work, 10-518-19
How buildings can be kept cold in summer, 10 519

Things to Think About

Why did Sir Richard Steele's fish die?
Why is natural ice packed in sawdust?
Why must food be kept at a low temperature?
Why is there no mess left behind when dry ice "melts"?
How may refrigeration help to make the human race stronger?

Picture Hunt

How is natural ice cut? 10 515-16
How is ice made in a cold-storage plant? 10 517
How does the electric refrigerator work? 10 518

Related Material

Who built their homes out of blocks of ice? 11 398
Why does ice float? 1 483
How is dry ice made? 1 406-8
How much ice cream is made in America each year? 9 338
How is meat shipped to distant parts of the country? 9-329
How does the gas refrigerator work? 1-409-10, 477
How is a current of air established in a refrigerator? 1 483
How are camp refrigerators built? 14-552

Practical Applications

How is mutton taken from New Zealand to England? 10 518
How is natural ice stored for use in summer? 10-515-16

Leisure-time Activities

PROJECT NO. 1: Make some ice cream.

PROJECT NO. 2: Make a camp refrigerator, 14 552

Summary Statement

Because bacteria cannot grow where it is very cold, we have learned how to freeze things, and one important advantage of this is that our food can be brought to us from great distances.

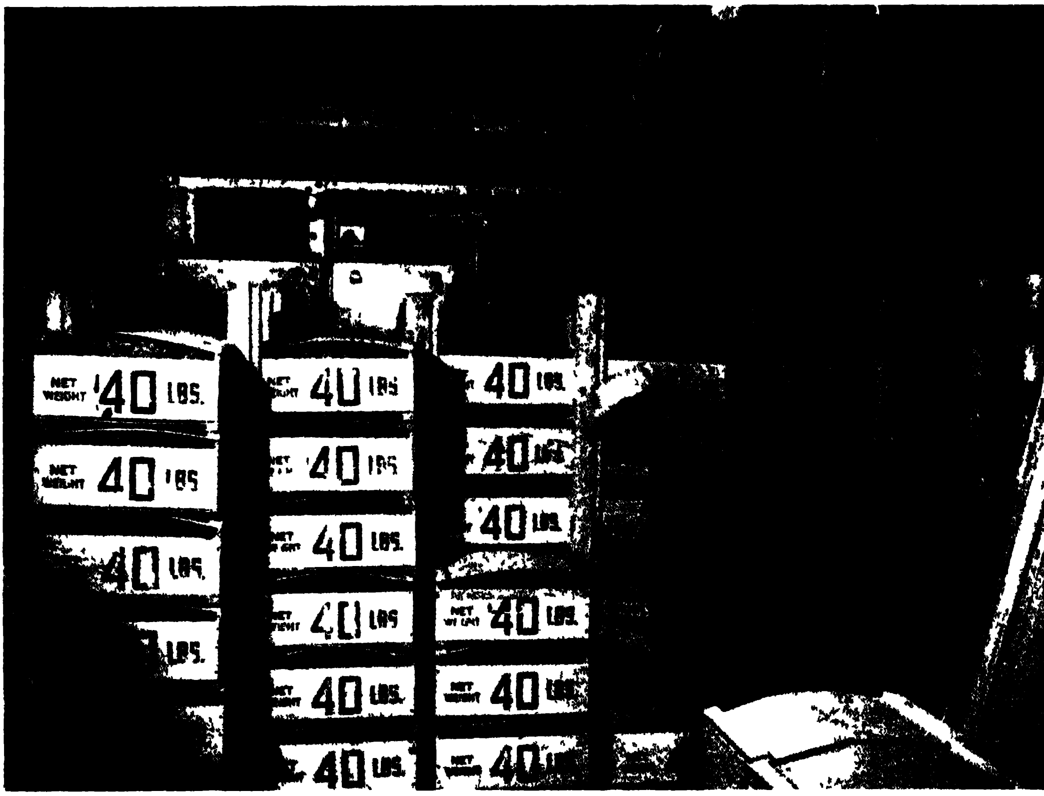


Photo courtesy Santa Fe Railway

This farmer is carefully stowing his crop of grapes inside a railway refrigerator car. Like the meat packer and the fisherman, the fruit grower is certain that modern refrigeration will keep his product in perfect condition even though it goes across the seas So he has not had to harvest his crop before it was ready to eat.

ALL *the* WAYS *of* FREEZING THINGS

Old Nero Used to Have Boxes of Snow Brought to Him from the Mountains. Now We Make Our Own Ice Right in the Kitchen

ABOUT two hundred years ago the famous author, Sir Richard Steele, thought he had a fine idea for getting fresh food out of the sea to all the people in England. For many of the people it was hard or impossible to have sea food, because the fish would spoil on the way to them. So Steele built some special boats full of water to bring the fish to shore, and some special water wagons to carry them alive all over the land. Then he thought he was going to get rich. The only trouble was that the fish did not like the notion. They are said to have battered themselves to death against the sides of the wagons The truth is probably that they died of the stale water

If Steele had killed his fish and packed them in ice, he could have sent them anywhere. But he did not have enough ice; for in the quantity he would have needed, ice is a fairly modern thing.

Of course there has always been ice in most parts of the world— in the winter time. But it was not cut and packed away to keep all summer, and there was no way to make it as we do now. In ancient days some fabu-

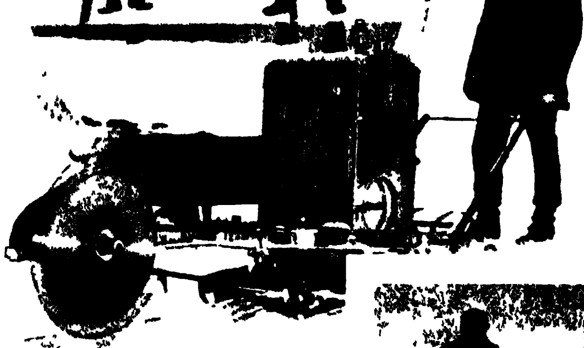
lously wealthy man might possibly have a little of it in the hot days. The Roman emperor Nero, for instance, used to make his slaves bring him boxes of snow all the way from the high Alps down to Rome. But ice for everybody, ice for carrying meat and vegetables all over the world, is a pretty recent luxury A hundred and fifty years ago there were no soda fountains, and very little ice cream; for people had just begun to cut up the ice on the ponds and rivers in the winter and pack it away for summer. It was in 1790 that the first blocks were cut and stored in America—from a pond in what is now the center of New York City.

But as soon as the ice business was started, it began to grow rapidly. Ice houses were built along the Hudson River, and ice merchants began to peddle their cold wares from door to door in many a town. Sea captains were soon taking loads of ice to tropical climes, even as far as India, and selling the glistening blocks at high prices.

How did they keep the ice from melting? Their only way was to keep the heat away from it. Now some things will carry heat far more than others. If we stick an iron bar into a fire, for instance, the end of it in our hand will soon be warm. But if we stick in a bar of wood we can hold it till it burns almost up to our fingers, for wood is a poor carrier, or conductor, of heat. And of course it is poorest of all when it is all chopped up into little bits. That is why we pack the ice in ice houses in sawdust; under this it will keep for a long time.

There are still ice houses in a good many parts of the colder countries of the world. In the winter the ice on a pond or river is cut out in squares by a machine or by a horse pulling a sort of saw over it. Then the blocks are taken to the ice house and packed away in stacks under the sawdust.

For many years we got all our ice in this way. It was by no means the best way. The water in the pond might be dirty or impure. The ice had to be carried a long way to people living in southern countries. And every so often the crop failed because the winter was not cold enough. So we have pretty much given up using natural ice, and now make nearly all we use.



The ice cutter in the center picture is shown going into action at Norway, Maine. It is propelled by gasoline, cuts along grooves already marked, and can do the work of more than a dozen men working in the old way with saws and a horse-drawn cutter, as shown in the other two pictures. One man and an ice-cutting machine can keep thirty-five men busy filling the ice house, and can harvest 760 tons of ice a day.

Photos by Keystone View Co

And what do we do to make ice? Curiously enough, we first start a fire. For we can use a fire to freeze things as well as melt them, just as easily as we can blow hot or cold with the same breath.

How We Make Ice

The fire makes the steam to run an engine, and the engine in turn operates the ice machine. This is a strange-looking contrivance, though it is really very simple. It merely blows out a spray of Freon-12 gas which is so cold that it will freeze the water near it.

For if a gas is suddenly released from pressure, it comes rushing out very cold.

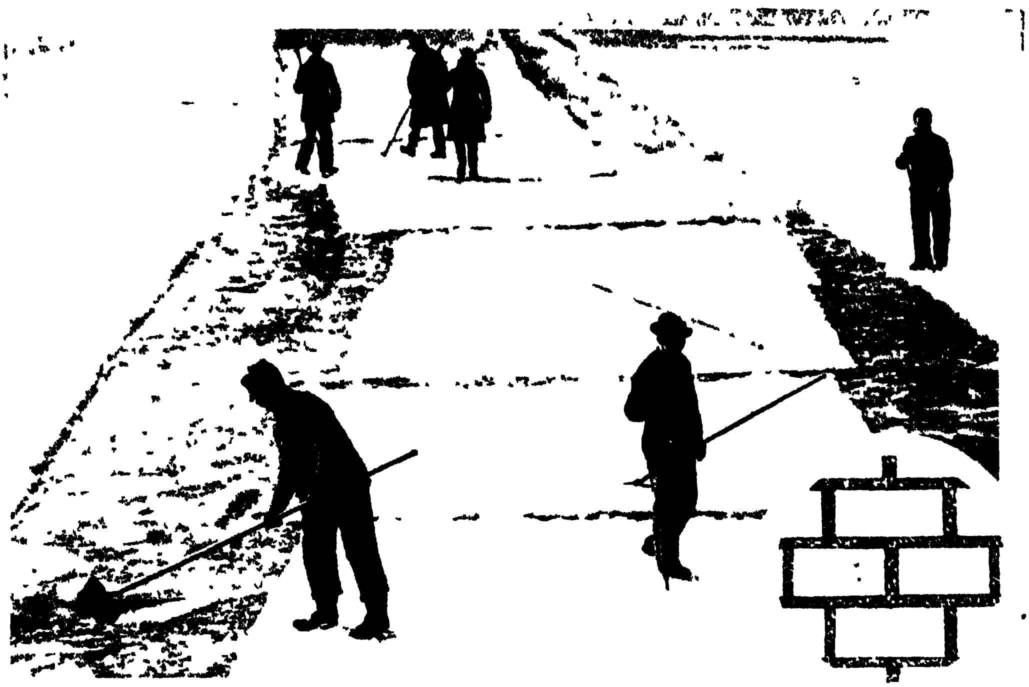


Photo by Keystone View Co

Harvesting the ice crop in the Charles River at Waltham, Massachusetts. Of course many crops of ice may be gathered in this way during a long, cold winter.

The inset shows the plan by which the blocks are packed in sawdust to keep the air out so that they will not melt when summer comes.

Freon-12 gas behaves in this way, and when the machine sprays it out of a little pipe and through a big one, it turns everything around the big pipe frigid. If the pipe ran through fresh water, for instance, the water would freeze at once, and the ice would have to be chopped away. So the pipe is run through brine, or salt water, instead, for salt water freezes only at a good deal lower temperature. It simply gets intensely cold. Then the brine is pumped around big cans full of pure fresh water. The water soon turns to ice, and the cans are then emptied of the clear, cold blocks that have formed in them. That is how we get pretty much all the ice we use in cities now.

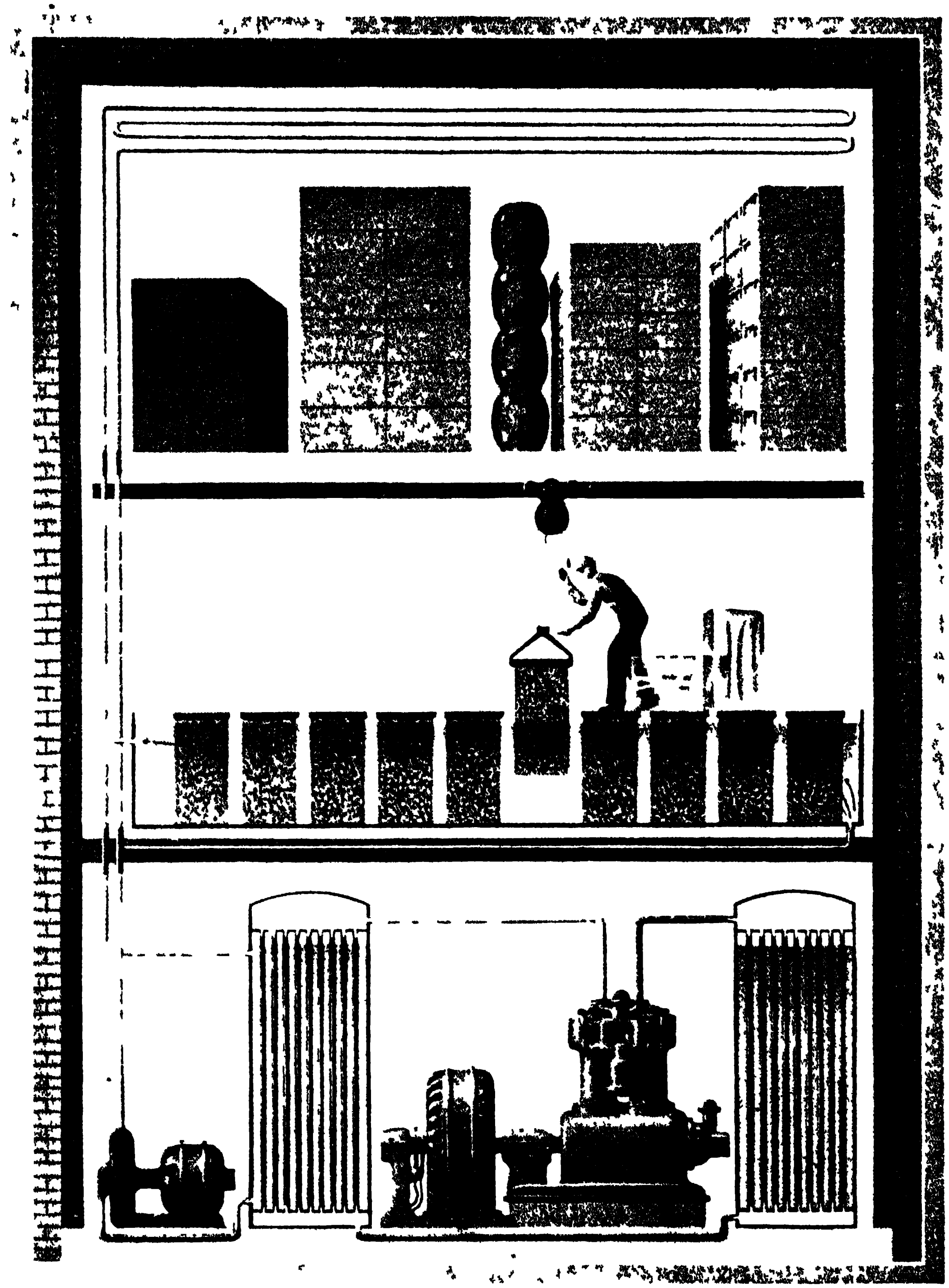
The Uses We Make of Ice

We all like ice for frosty drinks and dishes in the summer days. But it is still more useful in a number of other ways. Indeed, it is an absolute necessity if we are going to live the kind of life we are now used to. Nearly all our meat, and even more of our fish, comes to us in ice. Our eggs and butter, milk and cream, and fruit and vegetables would have a hard time traveling to us unless we kept them cold.

A Big Ice Box on Wheels

For all fresh food will spoil very easily. Tiny plants called bacteria (băk-tē'rĭ-ȧ) begin to grow on it and ruin it. They are far too small for us to see, but they will poison us all the same. But these bacteria cannot grow where it is very cold. So as soon as a side of beef leaves the hands of the butcher, it is kept cold to prevent any decay; and it is still cold when we buy it, a thousand or more miles away. In the same way our butter is frozen to keep it from going rancid, and many other things are kept frigid to prevent their spoiling.

A century ago we had to eat our fresh foods where they grew, and quickly. Now we have oranges and lettuce from California, beef and mutton from Chicago, and a hundred other things from a hundred other places. We can carry these things around the world, or keep them for months without

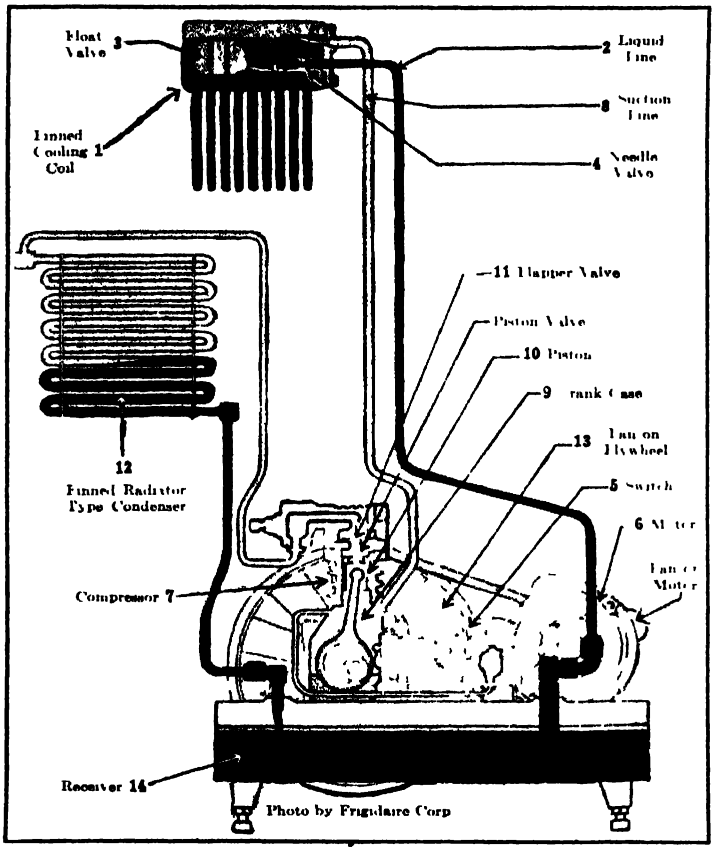


Nature makes winter with a breath of cold air Man makes it with a breath of Freon-12 gas In the ice and cold storage plant above, the refrigerating machines are on the first floor. There brine is chilled by a spray of Freon-12 gas On the second floor ice is made by sinking large tins of pure water in the icy brine Pipes of brine cool the air on the top floor to freezing Then the brine flows back to be chilled again.

harming them. Thus we not only have food from all over the world, but can even store up summer foods to eat in winter. For all his riches, Nero never had a tenth of the good things to eat that we can have now—and all on account of our cheap ice!

Of course we need special cars to do the carrying. The first refrigerator car was built in 1867, to carry meat from Chicago to New York. But refrigerator cars are no longer what they once were—just big ice boxes on wheels into which are loaded a few tons of ice. Now most of them are themselves great refrigerating plants mechanically cooled.

Ice has never been very useful for carrying food across oceans. It will melt before the boat gets over the sea. So the big boats carry a regular icing plant instead. Only the brine in the boats is not used to make ice, for that is not wanted. The brine merely flows through pipes around the bottom of the boat and keeps the storage rooms down there as cold as Greenland. On such a boat we can carry mutton from New Zealand to England, frozen all the way as hard as rock.



This is what happens inside your electric refrigerator. Liquid Freon-12 gas which is shown here by dark shading— is stored under pressure in the receiver (14) at the bottom of the refrigerator, and is supplied through the long tube (2) to the cooling coils at the top of the refrigerator (1). On the surface of the liquid in the cooling coils is a float (3) which controls a valve (4) that shuts off the supply of liquid when enough has flowed into the coils. The liquid Freon-12 gas absorbs heat very quickly from the air in the refrigerator, and part of the liquid so heated turns to gas. This gas, laden with heat which has been taken out of the air in the refrigerator, collects in the top of the coil until the pressure of it there is transmitted along the "suction line" tube (8) and closes a switch (5) on the electric motor (6). The motor starts working and operates the compressor (7), which begins pumping the heat-laden gas out of the coil (1) and down the suction line (8) into the crankcase (9). From there the compressor pistons (10) force it up through a valve (11) and out into the condenser coils (12). The fact that it is so greatly compressed in the condenser coils makes the gas get quite warm there; but the coils are cooled by the fly-wheel fan (13), and the compressed gas, freed of its heat in this way, turns back to liquid Freon-12 gas again and flows down into the tank it started from, at the bottom. In this way the turning of liquid Freon-12 to gas continually carries the heat out of that part of the refrigerator where the food is kept, and the electric motor serves to free the gas of its heat and turn it to liquid again.

On these cars and ships, as in the great cold-storage houses on land, every care is taken to keep out the heat. The doors are all made air-tight, and the walls are lined with cork or mineral wool; while dead air spaces are also left between the walls. In a word, a cold-storage plant is just like an enormous ice box. And down in the basement a pump is always sending cold brine through all the storage rooms, keeping them so cold that the men working in them need the warmest clothes even in the middle of July.

Kitchen ice boxes, too, were built to keep out the heat, and to make the precious ice inside last as long as possible while it kept everything cold. But the old-style ice box is almost a thing of the past. We now have

Photo courtesy Birds Eye Frosted Foods

Packages of peas are going into a frosting unit for quick-freezing a relatively new method of refrigeration. For many foods it is better than canning, since health-giving vitamins and garden-fresh flavor and color are "locked in" by this interesting process. But to achieve its end the freezing must be accomplished very rapidly.

our little ice machines in the home to chill the refrigerator. They do not pump ammonia and brine, as the big ones once did. Instead they commonly use Freon-12 gas, which is odorless and non-poisonous. Sometimes they run by electricity, sometimes by a hot gas flame. They make our own little blocks of ice and keep our food cold, too. We can even make ice cream in them.

One of these days we may all be keeping our houses cool in the summer, just as we keep them warm in the winter. Theaters, big shops, and some houses are now cooled in this way. Down in the basement there is an ice machine pumping cold brine through frosty white coils of pipe, and over the coils some great fans are blowing streams of air to cool it. Then the cool air flows up into the building. And even on the hottest day the air in such a building will feel fresh and comfortable.

One of the most interesting refrigerants is what we call dry ice. It is not really ice at all, for it is not frozen water, but a frozen gas the gas called carbon dioxide. When it "melts" away it does not leave any mess behind, but simply turns back into gas and floats off in the air It is far colder than ice 141 degrees colder, for its temperature is 109° below zero Fahrenheit. A pound of it will do the work of some fifteen pounds of ice, so we can ship a large carton full of ice cream with a little package of dry ice included, and have it arrive frozen harder than our ordinary ice would ever freeze it. Some time you may want to touch a piece of dry ice to see how cold it feels. But do not do so. It can injure your hands badly.

Very low temperatures are used in the newest form of refrigeration, also. The process depends upon quick freezing to preserve the flavor and vitamin content of foods For when a substance is frozen rapidly—say, within twenty-five minutes, as in this process the ice crystals that result are so small that they do not break the cell walls badly. The freezing machine is often taken to the source of supply, where the fruit, meat, or vegetables are frozen while they are absolutely fresh. The industry also maintains thousands of cold-locker plants, many of them cooperative, where for a modest sum one may rent a locker in which to store summer foods for winter use.

Reading Unit
No. 23

UNDER THE OCEAN WAVE

Note: For basic information not found on this page, consult the general Index, Vol. 15.

For statistical and current facts, consult the Richards Year Book Index.

Interesting Facts Explained

The kind of outfit divers use when at work, 10 522

What the suit and helmet are like, 10–522

The diver's telephone, 10 522

Why divers must come up very slowly, 10–524

How far down divers have gone, 10 526

What a diving bell is like, 10 525-26

How far down Beebe went in his diving bell, 10 526

Things to Think About

Why must the diver be an iron-worker, carpenter, and all-round mechanic?

How does a diver keep just the right amount of air in his suit?

Why does a diver who has been down two hundred feet need to take two hours to come up?

Related Material

Why is compressed air used in building tunnels? 1 461-62

How are tunnels built? 10-205-7

Why is it not possible to work very far below the surface of a river? 1 366-67

How are sponges gathered? 3-87

How are our pearls brought out of the sea? 3 162-64

What uses are made of compressed air? 1 462-65

Why do our ears close in a tunnel? 2 304

Why does water move very slowly at the bottom of the ocean? 1-67

Practical Applications

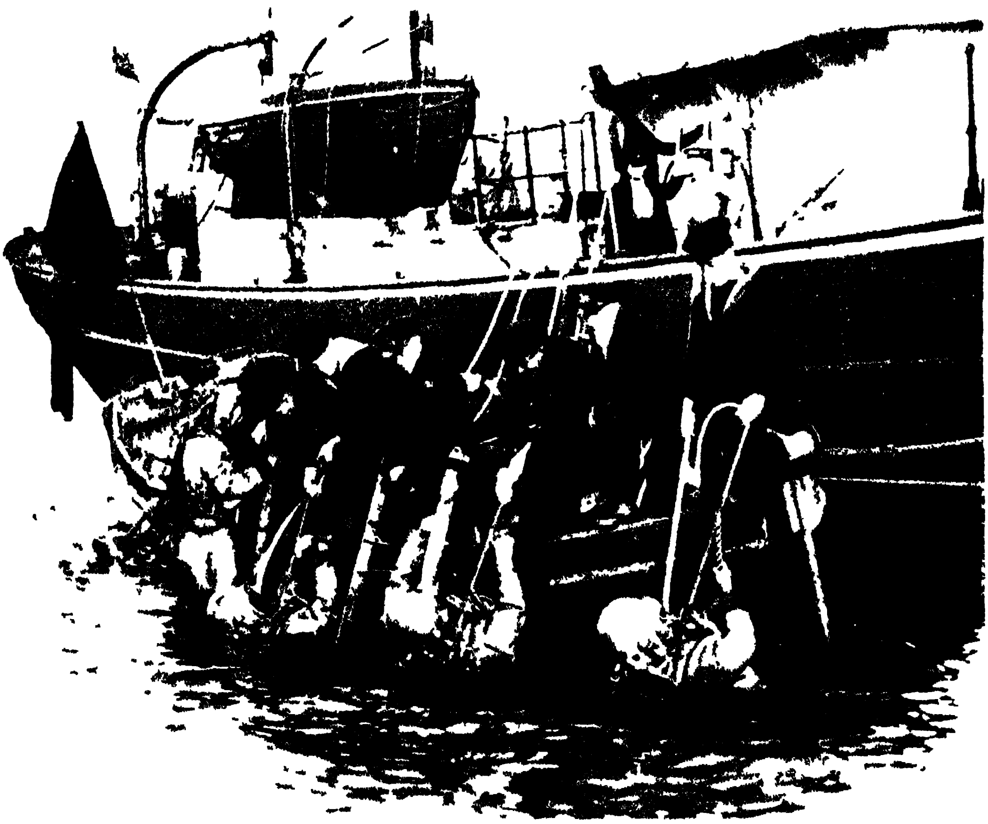
What made it possible to get back most of the gold that went down when the "Laurentic" sank? 10–524

What devices enable the diver to explore the water world? 10-525

Leisure-time Activities

PROJECT NO. 1: Make a model of a diving bell, 10 525

PROJECT NO. 2: Read Dr. Beebe's book "Half Mile Down."



This strange haul consists of four divers, sailors in the British Navy who are being trained at Portsmouth to go down to the ocean's floor. They are learning the most dangerous of all the world's occupations

UNDER *the* OCEAN WAVE

Where the Bold Diver Goes Hunting in the Watery Dark for Sunken Treasure

IT IS all very fine to take a flying leap off the bank and split the water for ten feet or so—but suppose you had to go on down two hundred feet farther, how would you feel about it?

Down there it would be dark and cold, and the two hundred feet of water over you would be very heavy. And if you started up to the surface for a breath, you would drown before you got there. So if you were going so far down, you would need a special sort of suit to keep you alive.

Yet people do go down as far as that, and farther still. Sometimes they do it just for fun, or just to see the sights. Oftener they are looking for treasure. For on the floor of the sea lies many a gallant ship that went down in a war or in an accident. In the real depths it will rest in peace, but in shallower waters the divers may get to it. It may still be carrying a great sum of gold that they can rescue, or it may even be brought up from the bottom to sail the sea once more.

For these and other reasons, men have been going down far below the waves ever since ancient times. Alexander the Great once went down to see what it was like. And of course they had some sort of special suit to wear. But it was only in the past

century that we reached the kind of outfit that is now used wherever the bold divers are at work. What is the outfit like?

In the first place there is the diving suit. It is like a great baggy set of overalls, made of stout cloth lined with rubber to keep out the water. At the wrists it fits so tightly that no drop can get through. And around the neck it has a metal collar on which the helmet fits.

The helmet is a brass globe with a window of thick glass on each side and in front. When it is screwed down on the collar it is water-tight. Inside there is a telephone with a bell button which the diver may press with his chin. And at the back is a stout rubber hose which brings down fresh air and also carries the telephone wires.

On the diver's feet are the heaviest shoes in the world. They are weighted with iron and they weigh about thirty pounds. Over his shoulders are slung two other weights, about forty pounds apiece, one on his chest and the other on his back. For there is so much air inside his outfit that he would float like a cork if he did not have these weights to take him down below. Indeed, he has a valve in his collar by which he can keep just the right amount of air in his suit; so on the floor of the sea he gets along well enough in his heavy shoes.

He carries down a "life line" for safety. With this he can give signals to the people up above, and can be pulled up again—in a great hurry if he has sent up that kind o signal.

Of course he has some kind of light, anc probably a very powerful electric one. Anc finally he takes down any tools that he may neec for the particular kind o work at hand.

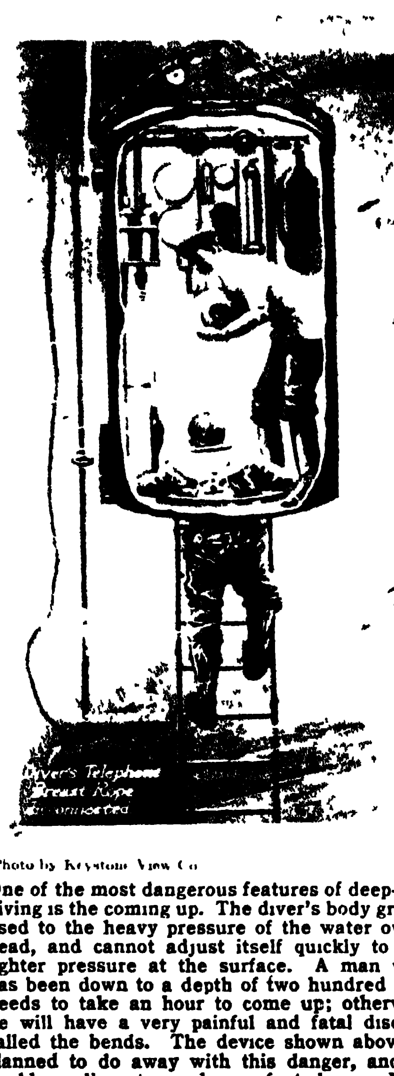


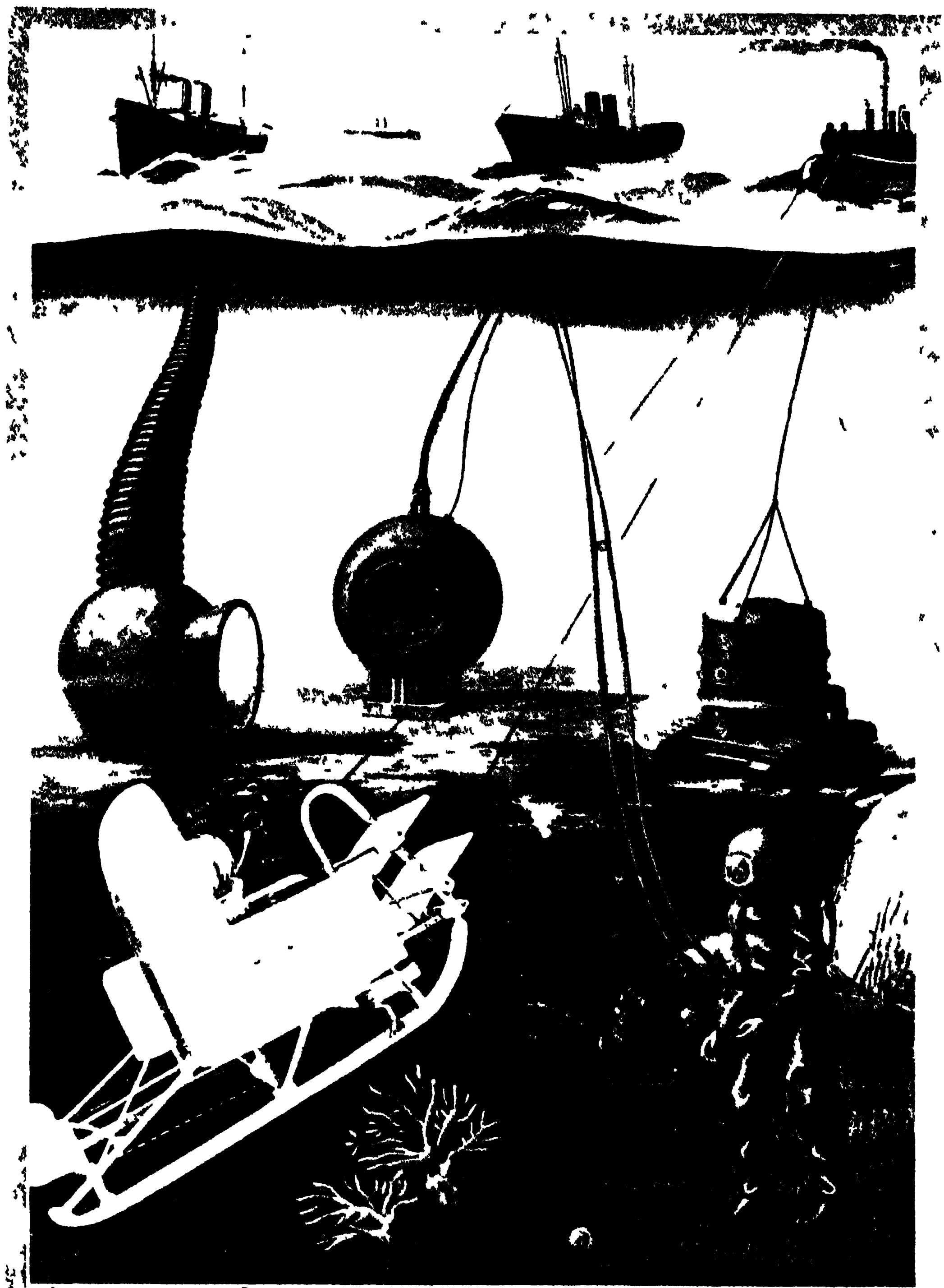
Photo by Keystone View Co

One of the most dangerous features of deep-sea diving is the coming up. The diver's body grows used to the heavy pressure of the water overhead, and cannot adjust itself quickly to the lighter pressure at the surface. A man who has been down to a depth of two hundred feet needs to take an hour to come up; otherwise he will have a very painful and fatal disease called the bends. The device shown above is planned to do away with this danger, and to enable a diver to work 350 feet down. It is called a submersible decompression chamber, and consists of a great diving bell, or small room, which the diver can enter from below on his way up to the surface. He is given oxygen to help in the removal of the nitrogen his system has absorbed at the great depths below. Sometimes a diver's underwear is electrically heated by wires insulated between two layers of fiberglas cloth.

And now that he is al dressed, we may lowe him beneath the waves It takes a brave man tc go down there all alone The sea creatures flocl around him, drawn by hi light, and some of then are anything but pleasan visitors. And it is lonely work looking around fo a wreck on the bottom o the ocean.

If he finds it, he clam bers on deck and begin to explore. Is there a door that will open? I so, he must make sure i *stays* open, and does no slam together to cut ol his air. In fact, he i going to find it harc enough to drag his ai line and his life lin through the winding cor ridors of the wreck anc still keep them alway clear.

In a dangerous searcl he may have a compan ion, and for a big piec of work even a gooc many. He may neec help to clear away th wreckage and get int the strong room for th gold or valuable papers But his best help may b an oxyhydrogen torcl that will cut through steel down below jus as we see it doing ever so often up on earth So the diver has to be an ironworker, car penter, and all-around mechanic. In fact to raise a whole boat he must be a bit of a



Tourist accommodations for deep-sea traveling! At the left is a diving tube, with a chamber at the end in which one may sit and watch the sea world swim by. To the right of the tube is a diving bell, which can go much deeper than the tube Next is an undersea tractor, to clamber over the ocean floor with an observer inside In the lower corners are a diving sled and a diver in ordinary deep-sea costume.

engineer. For he must tunnel beneath it, and pass chains around it that will pull it up. He does his tunneling with water. For a great hose comes down from above and shoots such a strong stream into the mud under the ship that a tunnel is soon cut through. It must be muddy work!

No diver can stay down very long, but the time depends largely on how deep he is. At a depth of two hundred feet, the weight or pressure of the water over him is about a hundred tons, and he rarely endures that for more than half an hour. But when he starts to come up, he takes an hour to do it! He goes up a little way and then waits for ten or fifteen minutes; then a little further, with another wait; and so on to the top.

The reason is that it takes time for him to get used to the lighter pressure. When the fish from far down in the sea are brought up to the surface they often explode because the great pressure to which they have been used is suddenly removed. The diver does not explode—he cannot go way down where those fish live—but he may suffer something nearly as bad. For when he goes down the pressure fills his blood with nitrogen; and as he comes back up, he can get rid of this only very slowly. So he must come up slowly. If not, he is likely to get the terrible disease that divers call the "bends," which is always very painful and often fatal.

When he has to come up in a hurry, on account of some accident, he can still be put into a tank under a strong pressure that is gradually removed.

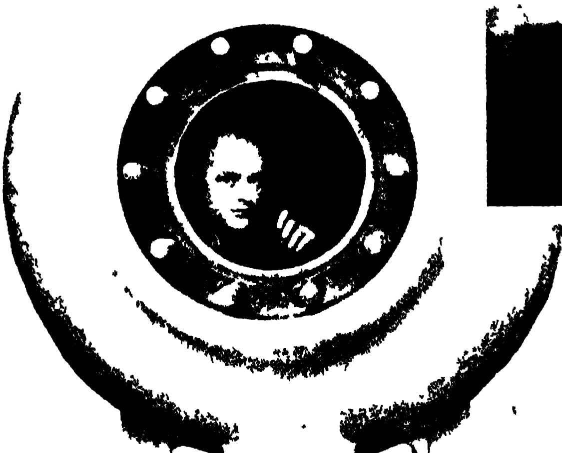
There are steel diving suits that are built to take the pressure off the diver. They look like great swollen iron men, with clamps for hands; and the diver works the clamps from inside. Of course these suits are more cumbrous, but they are safer in very deep water. There are also suits that carry no air line, but a tank of oxygen for the diver to breathe instead.

In both World Wars many a ship went to the bottom at the touch of a torpedo. Sometimes it was carrying a vast fortune in gold. Thus the "Laurentic" sank with $25,000,000 in her strong room. But she went down in only 135 feet of water; and in time the divers brought up nearly all the treasure. Other

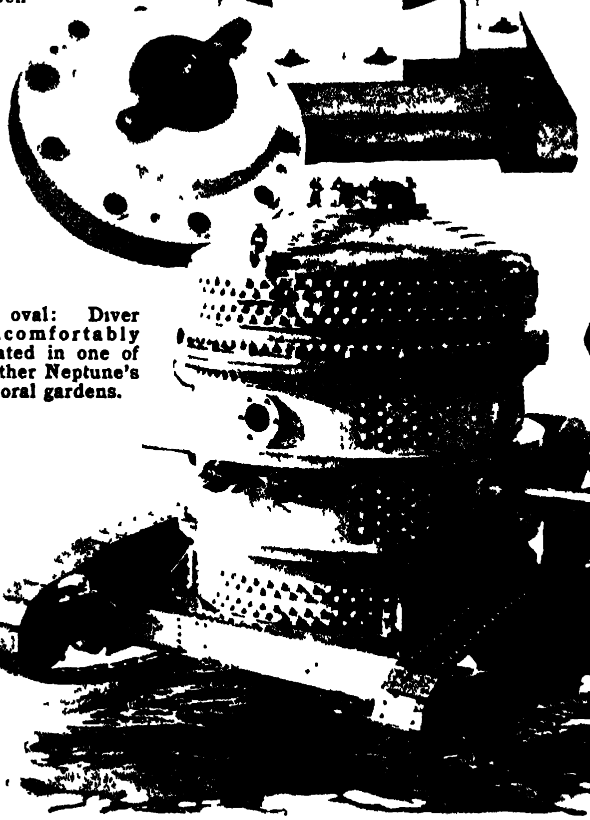
Photo by Keystone View Co

This daring diver is exploring a ship in 350 feet of water, a terrible depth for the human body to endure. But when he ascends, he will enter the decompression chamber some two hundred feet above him, and there get over the bodily effects of working so long with such an enormous weight of water on top of him.

This is the diving bell invented by Mr. Otis Barton, in which he and Dr. William Beebe, the scientist, went down over half a mile off the Bermudas, the deepest man had ever gone. Every square inch of its window of strong quartz glass had to stand a pressure of 650 pounds. In 1949 Dr. Barton went down 4,500 feet in the Pacific in a similar bell, which he calls a benthoscope. This descent holds the record In the upper right-hand corner is a diving-bell with open bottom The water is kept out of it by a heavy air pressure inside the bell



In oval: Diver uncomfortably seated in one of Father Neptune's coral gardens.



Photos by International News American Museum of Natural History, and Keystone View Co.

Above is the deep-sea tractor or tank, in which a diver can go exploring in the water world. The portholes let him see what is going on about him.

This diver is all ready to take his life in his hand and go down into the sea, where he cannot live for more than five minutes if his apparatus goes wrong.

Photo by U. S. Navy, and Deutschen.

In the large picture above you see a diver in the United States Navy about to make a descent. Before he goes under the water he will close the door in his helmet, which, as you see, is made of metal and can withstand a heavy pressure. In the inset is shown the strange, stovelike affair that has been designed for very deep diving. It has powerful "headlights," and its metal "hands" are operated by machinery inside the dress.

divers have been much farther down. The record for divers who make a descent directly from the surface in collapsible diver's dress is held by Max Nohl, who went down 420 feet in Lake Michigan. He carried oxygen and helium, for helium helps prevent the bends.

A great deal of less heroic but no less useful work is done by divers nearer to the surface. And of course a few men have been down far deeper than the record given a moment ago. But they were not true divers. They were in some sort of "diving bell," and a diving bell is a great box or ball of metal in which you can be let down into the ocean. The device in which Dr. William Beebe and Otis Barton went down more than a half mile in 1934 was called a bathysphere. It was in 1949 that Barton set the record of 4,500 feet in a benthoscope weighing 7,000 pounds. It was designed to go to the ocean bottom, while the bathysphere was meant to go only part way.

The STORY of IRRIGATION

Reading Unit
No. 24

HOW WE MAKE THE DESERTS BLOOM

Note: For basic information not found on this page, consult the general Index, Vol. 15.

For statistical and current facts consult the Richards Year Book Index.

Interesting Facts Explained

How the crops in the Nile valley have been watered from earliest times, 10 528-29

How the science of irrigation has spread, 10 529

Dry deserts, where tall cactus plants stood sentinel, 10 530

How water was first lifted out of rivers, 10 529-30

Why America has built great dams, 10 531

Measuring the amount of water the rancher uses, 10 532-33

How water gets into the irrigation ditches, 10 532-33

Where gardens are being made out of barren deserts, 10–533

Things to Think About

Why must the rancher be something of an engineer as well as a farmer?

What part does the dam play in irrigation?

How much land in the United States has been saved, and in what part of the country are the biggest dams found?

What important work does the Bureau of Reclamation have to do?

Picture Hunt

What kinds of devices for getting water were used in Persia and Egypt? 10 529, 532

What methods of irrigation are used to-day? 10–528, 530-33

Related Material

How does Nature protect plants so that they can live in the desert? 2-203-7

How does the stem of a plant take water and mineral substances from the root to the leaves? 2-28-33

What kinds of birds live in marshy areas? 4–100-11

How is land irrigated in Holland? 6–352

How does rainfall affect plant life? 2 193, 197

How is water pumped great distances? 1-464-65, 10-537-38, 541

Practical Applications

How is dry land reclaimed? 10–528, 533

What problems cause most concern on irrigated ranches in California or Idaho? 10–531-33

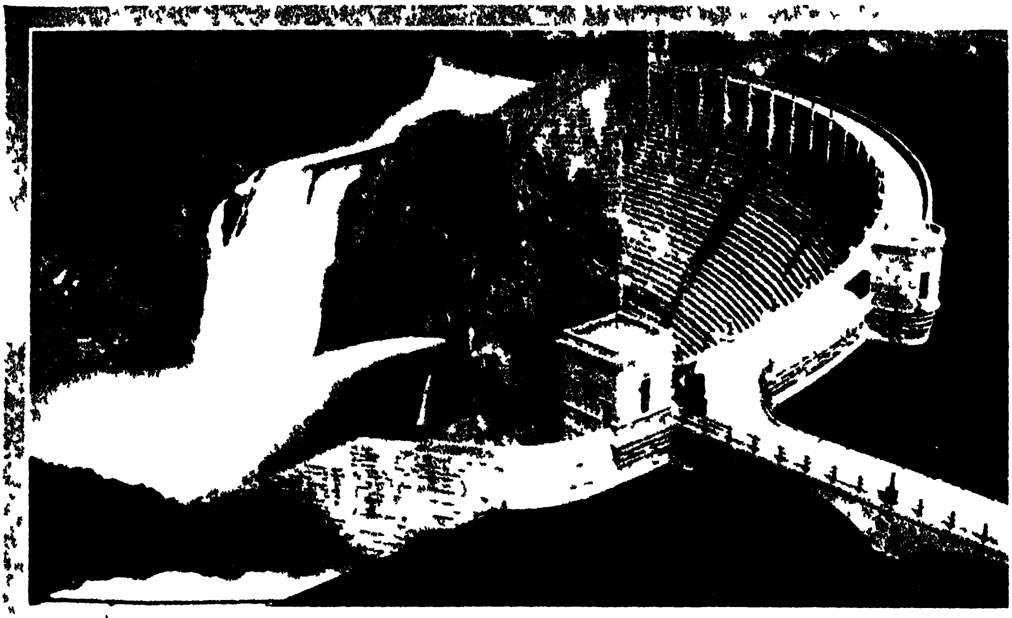


Photo by U. S. Dept. of Agriculture

This great arc of masonry is the Roosevelt Dam, in Arizona. The reason for its being curved in this way is that it thus offers more resistance to the tremendous pressure of the water above it. There is a spillway on each side to let some of the water past, and discharge pipes, which we can see in operation. In the great reservoir above the dam, it has been said, is enough water to cover the whole state of Delaware a foot deep. The Roosevelt Dam is, of course, named after Theodore Roosevelt, who as president did more than any other one man ever did to help "reclamation" in America. He himself opened the dam in 1911.

HOW WE MAKE *the* DESERTS BLOOM

This Is the Story of the Way We Carry Water to the Rainless Areas of the World and Make the Dry Lands Wave with Green

HAVE you ever watered the garden with a watering can, or tried to manage the hose on the front lawn? Then you know how thirstily the grass and flowers drink up the moisture in a dry summer. But suppose you had a whole big field of corn or cotton to water. If you worked all day with a garden hose you could sprinkle only part of it, even if you had plenty of water to draw upon. And often there is no water at hand. So usually the farmers just wait for rain.

Yet there are parts of the world—as you know very well if you happen to live in one of them—where so little rain falls that the crops would wither and die waiting for it. At the same time, these may be very pleasant places in which to live, with their long weeks of sunshine and their fertile soil. The only thing lacking is water.

So for four thousand years or more, men have been working at ways to bring water to the deserts and make them "blossom like the rose." We call this process "irrigating" (ĭr'ĭ gāt) the land, which is only a more technical word for "watering" it. Almost every country you can think of has some land under irrigation (ĭr'ĭ gā'shŭn) to-day. There are some hundred million acres in the United States alone.

From the very earliest times of which we have any knowledge, all the crops in the fertile valley of the Nile have been watered by irrigation. Every year the great river rises in flood, and for centuries the waters were allowed to spread out all over the farm

lands. The flood waters brought with them a rich silt from up the river and left it to make the land more fertile; at the same time enough moisture soaked into the ground to last through the season for planting and growing wheat. And where the waters would not naturally have spread, they were led by canals and then spilled out into other basins or valleys, to water the grain. Thus the valley of the Nile, where rain practically never falls, became one of the most fertile and powerful kingdoms of the ancient world, and later the great "granary" of the Roman empire.

But when the flood waters had drained off and the river had gone back between its banks, it was hard to lift any more water up on the land, even if the crops were dry. There were the crops, and there was the water, anywhere from three to twenty feet below. But there were no pumps to lift it up. How was one to get it to the land?

One very simple device was to take a wooden pole and balance it at the meeting of two slanting posts or over the crossbar between them. At one end our Egyptian would hang a skin vessel to dip up the water; at the other he would fasten a stone or lump of clay heavy enough to swing the full waterskin into the air, where it could be emptied into a trough leading off among the rows of wheat. Then he would pull down on the pole and lower the empty skin into the water for another bucketful.

Photos by American Museum of Natural History and Visual Education Service

Here are two primitive ways to raise the water to thirsty land, both still used in the Orient. Above is an Egyptian shadoof, the working of which is described in this story. Below is a Persian device using a wheel and leathern buckets.

There were other simple devices. He might attach an endless chain of buckets to a wheel, and arrange the wheel so that it could be turned by an ox or an ass walking around and around. The cleverest way of all was the Archimedes (är'kĭ-mē'dēz) screw. A long cylinder was laid on an incline that had its lower end in the water, and inside the cylinder was a long screwlike contrivance, which was turned with a crank. This revolving screw scooped the water out of the river and passed it up and up through the cylinder, very much as if the water were going through the locks of a canal. All these devices for lifting water are used in Asia to this day.

But if you journeyed up the Nile to-day, you would see few farmers trying to irrigate their lands with any such crude instruments as these. There are power pumps, of course, which will lift all the water needed from the river below. Besides, a whole system of dams and reservoirs and canals has been worked out, so that the flood waters may be used anywhere and at any time they are wanted. One of the greatest dams in the world is at Aswan (ä-swän') in Egypt.

For the science of irrigation has been spreading and developing ever since these ancient days four thousand years ago, when it appeared in Egypt. Even in very early times the people along the Tigris and Euphrates rivers probably had some sort of irrigating system. The idea may have been

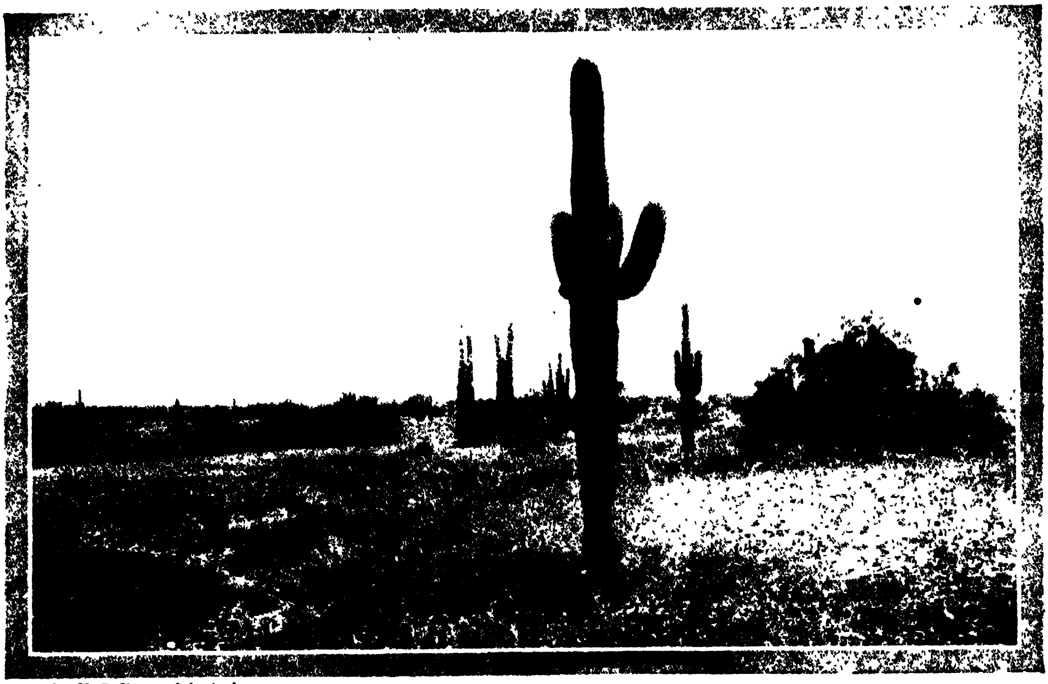


Photo by U. S. Dept. of Agriculture

Mile after mile, the desert lay dry and burning in the sun. Parched desert vegetation grew on it, and the tall, fantastic cactus plants stood sentinel over it, like ghosts of strange, prehistoric monsters.

Photo by U. S. Dept. of Agriculture

Then someone built a great dam many miles away in the mountains, and guided the waters through long canals and big flumes and smaller flumes until it ran out over the desert in tiny rills. Then someone planted fruit trees, and they took root and grew. And now the desert has burst into bloom!

brought to Europe by the Moors, when they conquered Spain. That is more than twelve centuries ago. But it is only very recently that modern engineering has made irrigation so simple and sure that it grows crops better than ordinary rain does.

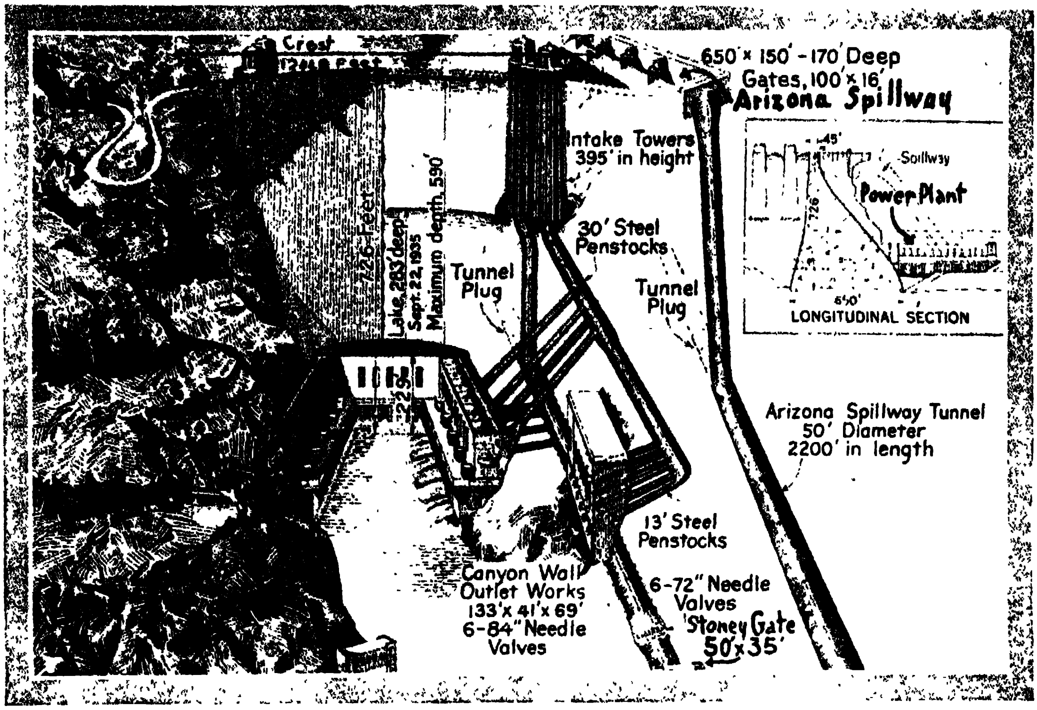
The first problem is still to lift the water up, because when it is once lifted high enough it will flow downhill naturally and can be guided over the land. If a farmer lives near a river, he may still get the water right out of the river itself; in the United States there are a great many irrigation pumps, some so big that they are rated in thousands of horse power, others so small that a little gasoline engine can run them. Water pumped up in this way—how much easier than pulling on a pole or belaboring a poor ox! may be fed into the small ditches and runnels, and guided over the fields.

The water from Coolidge Dam, Arizona shown above—has turned thousands of arid acres into fertile farms through a system of irrigation canals like that shown below.

But very often this cheap and easy way of irrigating is not possible. Then the first step is to build a dam across a big river high up above the lands to be irrigated. A dam, of course, raises the water above it still higher, and the water can be led off into canals. These take it to smaller canals or flumes, and these too branch out, and so on until it runs out into the tiny grooves or runnels between the trees or plants in the fields. The great dams are made with sluiceways, gates or outlets which can be opened or shut, and in this way the flow of the water can be regulated. Often artificial lakes are formed above the dams, and in them water is stored during flood season and let out gradually during the dry summer, whenever it is wanted. These lakes are called reservoirs.

Of course it costs a great deal of money to build the tremendous dams and reservoirs and all the canals and flumes. In the United States, many hundreds of millions of dollars have been spent on irrigation. Quite a large part of the work has been done either by corporations or by coöperative societies of the farmers or ranchers who use the water. But the very biggest projects have been managed by the government. It built, for instance, the Elephant Butte Dam in New Mexico, the Roosevelt Dam in Arizona, and the Arrowrock Dam in Idaho; its finest achievements are Hoover Dam on the Colorado River in Nevada, Grand Coulee Dam on the Columbia in Washington, and Shasta Dam on the Sacramento in California. At Washington there is a Bureau of Reclamation to look after these things. Is that not a good name for a bureau to have—"reclamation" (rĕk'lȧ-mā'shŭn), which means "reclaiming" or "saving"? The Bureau has reclaimed millions of acres of land.

But if you suppose that when the water is brought to the farm or ranch there is nothing more to be done about it, you are very much mistaken. Indeed, if you happen to live on an irrigated ranch in California or Idaho, you will already be smiling at such an idea. On such a ranch the talk is not about whether the wheat is getting enough rain or whether there will be a storm to spoil the hay; rather it is about the high price of water, and



How many superlatives we should need to describe Hoover Dam on the Colorado River! It is the highest dam in the world; its reservoir is the world's largest artificial lake; in every way the work is stupendous, as the diagram shows. This great irrigation project waters almost two million acres, including Imperial Valley in California. But most amazing and heartening of all is the fact that this is only the beginning of the marvels to be achieved by man's coöperation. Millions of people working together can perform miracles.

Photo by James's Press Agency

Though Egypt has been an irrigated country from the dawn of history, it is only during the last century that she has had a system which gave the land enough water all the time without ever flooding it. The British are largely responsible for the new system, which they introduced primarily to make it possible to grow cotton. Its very heart and center is the huge Aswan Dam at the First Cataract of the Nile. This great engineering achievement, shown in our picture, was completed in 1902 and made higher in 1912. The dam is nearly 1¼ miles long. When the sluices are closed, the water gathers into a lake 200 miles long.

Photo by Elliott Means

To irrigate this Texas cotton plantation sections of flexible rubber hose are used to syphon water into the cotton field from a main irrigation ditch. This provides a flow of water which can be regulated and directed according to need. The hoses are light enough to be carried easily from place to place. In order to start the siphon working the entire hose is filled with water. While one end is kept in the water, the other end is covered by the hand and carefully placed in the field so that it is lower than the level of the water in the ditch.

whether the main flume needs repairing, and how hard it is to get the water not to flood in the north hollow and leave the south rise dry. For of course the rancher has to pay for his water, since it costs so much to get it to him. Clever ways have been worked out to measure the amount he is allowed to have and the amount he actually uses and has to pay for. And the main care of our rancher is to see that his precious water is used in exactly the way in which it will do the most good.

There will be a canal or a wooden or concrete flume running somewhere near our ranch, and somewhere along it will be a sluiceway, through which our supply of water comes into our own irrigation ditches. These ditches have to be laid out in just the right directions, so that the little runnels they feed will not be trying to run uphill. Often much work has to be done in leveling the fields to let the water run all over them. The rancher has to be something of an engineer as well as a farmer.

While the water is flowing, men have to be working all the time clearing away clods and hummocks, guiding the water, seeing that enough of it gets everywhere and not too much of its gets anywhere. And our rancher has to know just how much water his particular crop needs, and how often. For instance, alfalfa needs to have the whole field flooded and then drained again. Orange and lemon trees need less water than potatoes. And as for rice, it literally grows in water. That is why rice is irrigated even when there is heavy rainfall. In the United States, there are over a million acres of irrigated rice fields in Louisiana and Arkansas, where it rains nearly every day!

The farmer should know just what kind of soil he has to irrigate, too. If the soil is tightly packed, he will let the water in very slowly and over a long period of time. If it is loose, so that the water soaks in rapidly, he will let the water in faster and the irrigation period will be shorter. Some of the water always evaporates.

Thus in many regions of the world men are making gardens out of barren deserts. India, with her starving millions, has resorted to irrigation to feed them. Russia, Japan, and Egypt have vast irrigated tracts. France and Italy and Spain have several million acres apiece. Rice and golden grain and rosy-cheeked apples sprout and flourish where once there were only sagebrush and prickly cactus.

Reading Unit No. 25

HOW A CITY GETS ITS WATER

Note: For basic information not found on this page, consult the general Index, Vol. 15. *For statistical and current facts, consult the Richards Year Book Index.*

Interesting Facts Explained

The amount of water each American uses every day, 10 535
How the Romans brought a plentiful water supply to their cities, 10-537
Why towns were built on either side of streams, 10 537
Why artificial lakes of water are called "reservoirs," 10 538
Why our water supply has to be pure, 10 542
How our water is purified 10 542

Things to Think About

Why do we build towns near lakes and rivers?
How did the Romans use gravity to get the water to their cities?
Why are water-supply systems very expensive?
How does our water supply affect our health?

Picture Hunt

How is a large volume of water carried across mountainous country? 10 536, 541
How is pure water carried across rivers and bays? 10 538

Related Material

Why should we drink plenty of water? 2-420
What precautions should campers take against bad water? 14 554, 556
Why is water an excellent fire extinguisher? 1-385
How much water is there in our blood? 2 345
Why does the presence of algae in our water make it taste unpleasant? 2 68
How do pumps work? 1 464-65
Which water-borne bacteria cause disease? 2 12-21
Why do we perspire? 2-293

Practical Applications

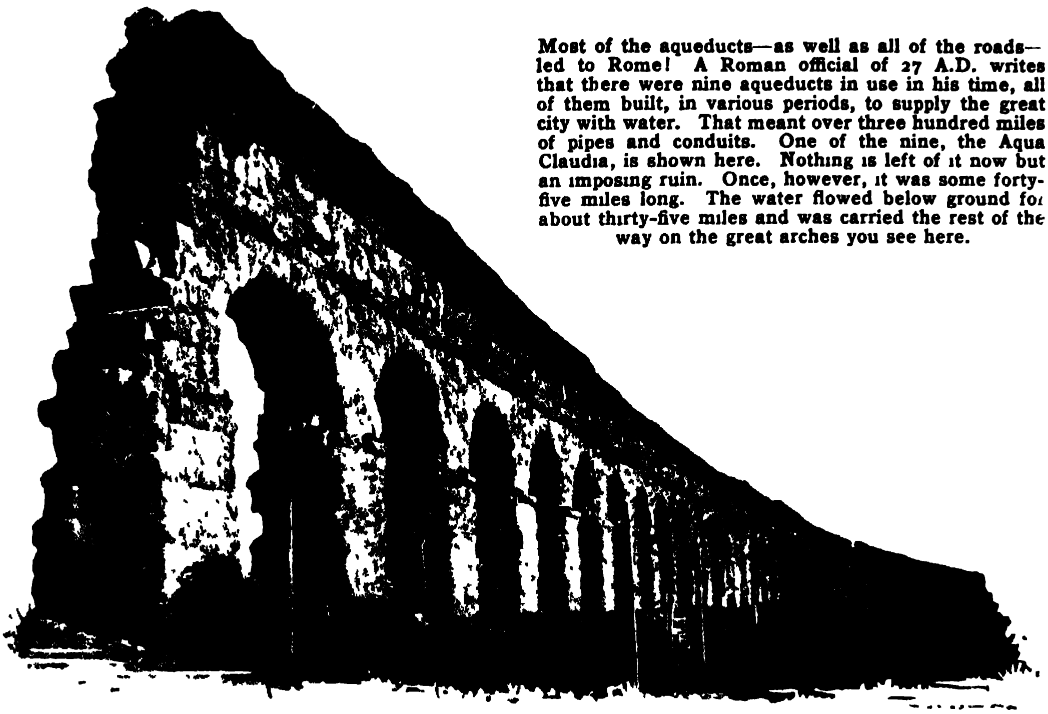
How does a city get its water supply? 10-535-41
How is water distributed in a large city? 10 539

Leisure-time Activities

PROJECT NO. 1: Visit your city's water-supply plant.
PROJECT NO 2: Make some muddy water clear by allowing the sediment to fall to the bottom, 1 49

Summary Statement

Because we must have pure drinking water, our cities build reservoirs and pipe systems to give us our supply, and they also install various means of removing harmful materials and living organisms from the water before it reaches us.



Most of the aqueducts—as well as all of the roads—led to Rome! A Roman official of 27 A.D. writes that there were nine aqueducts in use in his time, all of them built, in various periods, to supply the great city with water. That meant over three hundred miles of pipes and conduits. One of the nine, the Aqua Claudia, is shown here. Nothing is left of it now but an imposing ruin. Once, however, it was some forty-five miles long. The water flowed below ground for about thirty-five miles and was carried the rest of the way on the great arches you see here.

Photo by Chauffourier Rome

HOW *a* CITY GETS ITS WATER

Do You Know That Every Person in Town Needs About a Hundred Gallons of Water a Day? What Do You Think He Does with It? And How Does It All Come to Him?

WHENEVER you go camping in the forest or mountains, you pitch your tent beside a stream or spring or lake. If you started to build a house in an unsettled country, you would try to place it near water; otherwise, about the first thing you would do would be to dig a well. Just so, if you were planning a town or city, you would think at once about the water supply. We simply cannot live without water. Americans, in fact, use some hundred gallons of it apiece every day of their lives.

Now if you take a bath every day you cannot use up more than about ten gallons a day in that way, and you will hardly drink more than two quarts. Of course you wash your hands a good deal, usually under a stream of running water most of which you never use at all; and there is a good deal of boiling and washing of clothes and vegetables and other things going on in the kitchen But we could never come near that hundred-gallon mark if these were our only uses for water.

A great deal of the rest is simply wasted Water mains leak, and so do faucets. How many times have you lain awake in the night and counted the drip-drip-drip of water dropping into a sink or bowl? Besides, we never think anything about letting a faucet run hard and long—is there not always more water where this came from? In some cities water meters are set like so many watch dogs to measure what we use, and every month a bill comes around. And in those towns the amount of water each person uses magically drops to less than half!

Yet the city itself uses up a good share of

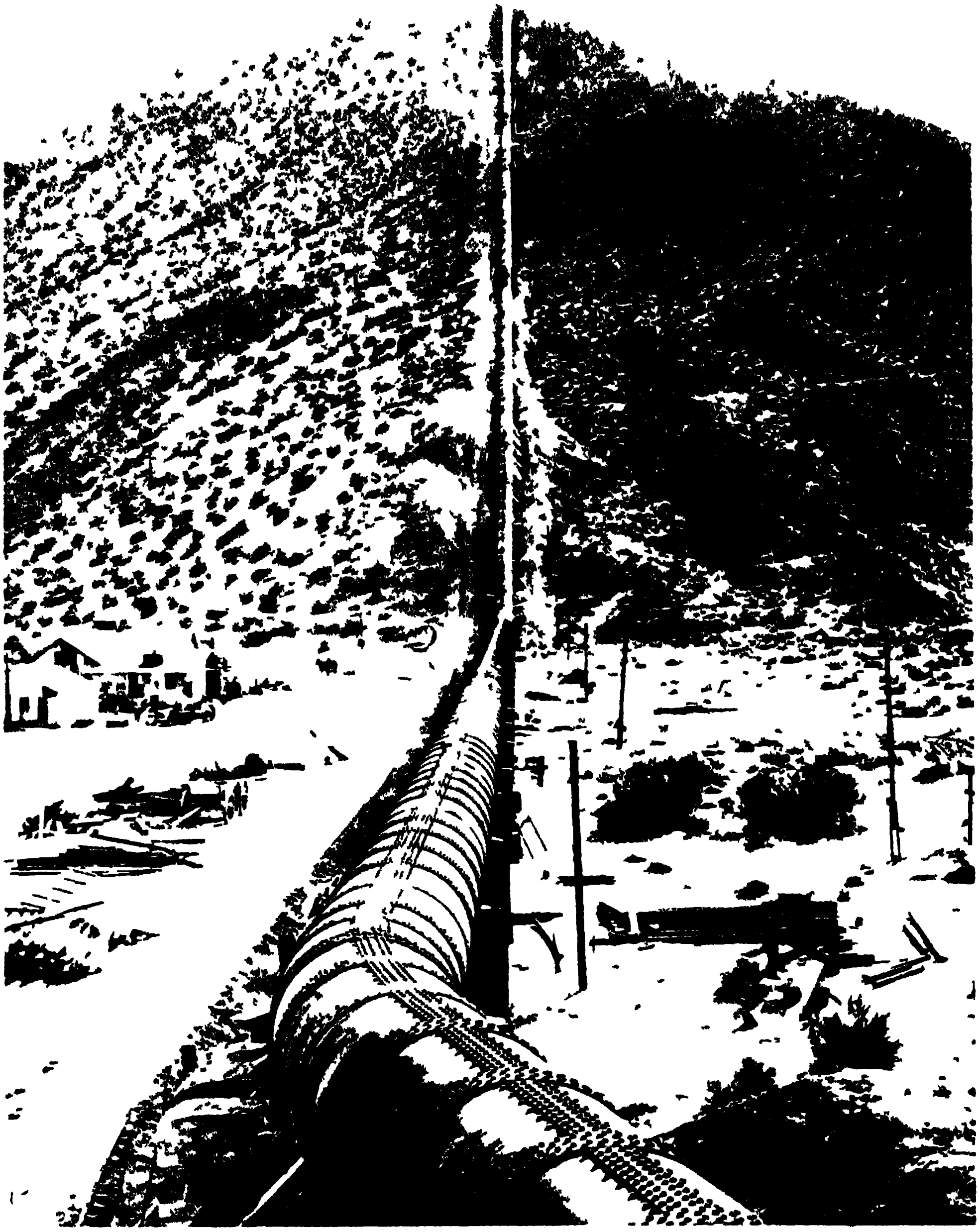


Photo by Los Angeles Calif C of C

This is a section of the great pipe line which travels many miles over mountain and valley to bring pure water to the great city of Los Angeles, in California One wonders what the Romans would think of it.

our hundred gallons—to wash or sprinkle the streets, flush the sewers, put out fires, and make the grass and flowers grow in the parks And laundries and factories use a great deal of it, too, and plants for making ice, and a hundred other things

HOW A CITY GETS ITS WATER

Now just suppose that instead of merely turning on a tap you had to carry water from a river half a mile away, or pull up a heavy bucket from a well! Yet it is only in very modern times that pumps and pipes and dams have done all this work for us.

In the long ago, to be sure, streams were made to flow through royal gardens and water was piped to royal fountains. There were no pumps, and no steel or iron pipes; but pipes could be made of lead or hollow logs, and pumps are not needed if you can arrange for your water to flow downhill. So barbarian kings could listen contentedly to the splashings of fountains in their courtyards, and barbarian princesses could walk in their gardens by quiet pools of cooling water.

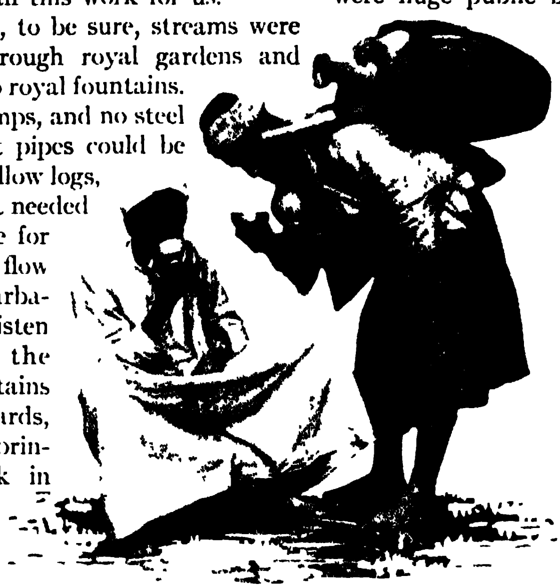


Photo by Visual Education Service

Here is a water carrier of Egypt. To fill his cup he needs only to bend over and let the water come pouring out of the jug on his back.

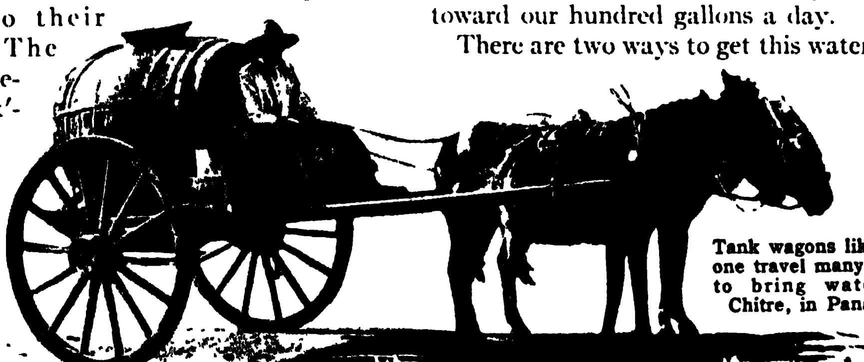
But as for ordinary people, they were lucky if there was a stream or a well not too far away. No daily baths for them! Rather the housewife must go every day to the village well with her buckets or waterskins, and her earthen vessel on her head. Do you remember the pretty story, told in the Book of Genesis, of how the lovely Rebekah was wooed as she drew water at such a well? Nor was the village pump of our own great-grandmothers' day much more convenient.

The Romans learned how to bring plentiful water to their cities. The great aqueducts (ăk′-wē-dŭkt) by which they brought it down from the distant mountains were almost as famous as Roman bridges and roads. Only the very wealthiest citizens could afford to have it piped into their houses, but there were huge public baths which the citizens could enjoy, and numerous public fountains.

In those days, and all down through the Middle Ages, the safety of a town often depended on its water supply. For if an enemy sat down around the walls, the besieged people could hold out only so long as they had water. If the enemy should somehow cut off the supply there would be nothing for it but to surrender. This was one more good reason for setting a town across a stream—then the water was safe inside the guarding walls.

By the opening of the seventeenth century we begin first to hear of pumps and reservoirs, things that sound like modern waterworks. About that time a pump began to lift water from the Seine for the people of Paris. The joyful citizens named it "La Samaritaine" after the Samaritan woman who talked with Jesus as she drew water from a well. In London the first reservoirs were built in 1609. Since then we have come on pretty fast toward our hundred gallons a day.

There are two ways to get this water to us.



Tank wagons like this one travel many miles to bring water to Chitre, in Panama.

Photo by Presse-Photo Service, Berlin

Photo by N Y C Board of Water Supply

Hills and valleys are but a few of the engineer's problems in building an aqueduct Often the water, in its journey from reservoir to city, must cross rivers and streams The boat to the right is scooping out a trench in the bed of the Hudson River Through it a pipe line will be laid to New York City

The older and simpler—that used by the Romans—is by means of gravity (grav'i tĭ) The engineers select a clear and constant stream in the hills as near as may be to the town, and build a dam across it to catch the water Above the dam the water spreads out into an artificial lake, called a "reservoir" (rĕz'ĕr-vwôr) because it "reserves," or stores the water. From the reservoir the water is led away by a huge pipe, called an aqueduct after those built by the Romans It flows in this way down from the hills into smaller reservoirs, which in their turn feed the supply mains or chief pipes in the town There are supply mains under almost every city street, and small pipes branch off from them at every house or other building As you have guessed, we call this a gravity system because the water runs downhill all the way, and so the pressure is all a result of the force of gravity, which pulls the water down

But sometimes a city has no hills on which the engineers can build a reservoir Then they must pump the water up, from river or lake if it is handy, or from deep wells Sometimes they pump it right into the supply mains Sometimes they store it in a grea towerlike tank called a standpipe, from which it can flow down into the mains by gravity as well as if the tank were on a hill

Our Water Costs Us Millions

All this sounds simple enough, but it is really a great deal of work and hugely expensive The cost of New York City's Delaware aqueduct and reservoirs is estimated at $500,000 000 Chicago spends millions pumping water out of Lake Michigan Los Angeles spent $25,000,000 for one reservoir and aqueduct and put $200,000,000 into another There are so many difficult things to do that the work becomes very expensive Reservoirs have to be built or pumping stations erected, thousands of miles of pipe have to be laid, tunnels must be driven in the rock, and siphons made to shoot the water down and then up again under rivers To supply New York, there is a water tunnel fifteen feet in diameter, driven through solid rock from three to seven hundred feet below the surface, and in 1932 another tunnel had to be built in addition Even the cast-iron

Photo by N. Y. C. Board of Water Supply

Part of New York's water supply comes from a sunlit lake called the Ashokan Reservoir; it lies high up in the Catskill Mountains. Ninety-two miles of shafts and tunnels carry the water under valley and through hill. Two other reservoirs store it until it is needed. Finally it reaches New York and, far below the surface of the ground, it is distributed through the great city by means of tunnels like the one you see in the picture.

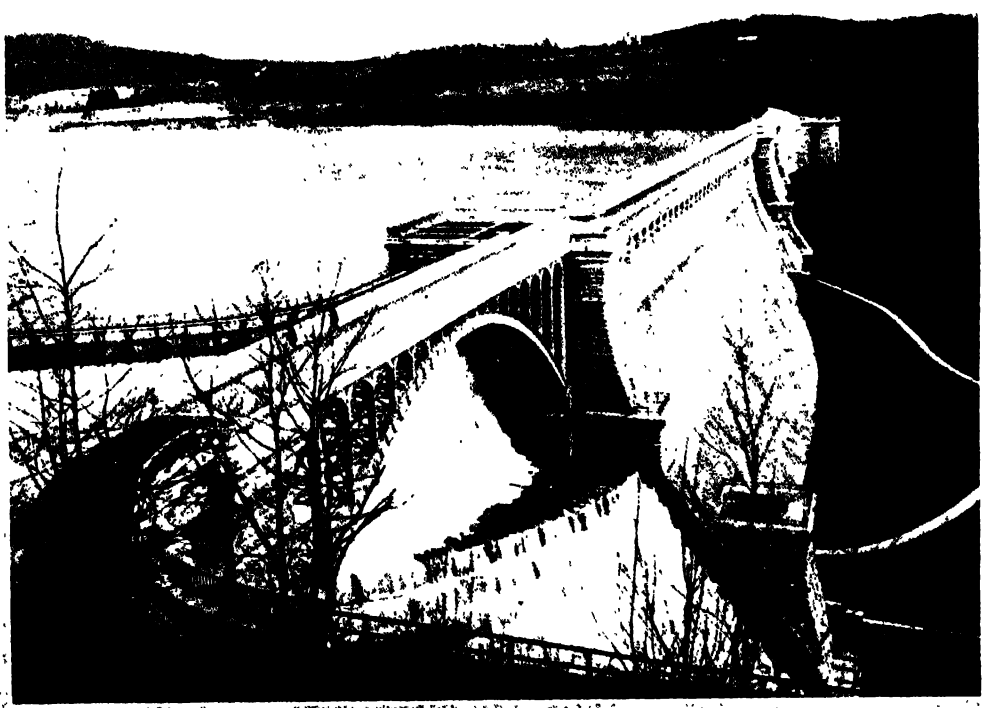


Photo by N. Y. C. Board of Water Supply

This is Croton Dam, another of the carefully constructed dams which store water so that the great city of New York may have plenty for all its needs even in times of drought.

Photo by N. Y. C. Board of Water Supply

he fountains of Versailles are scarcely more beautiful than the aerator of the Ashokan Reservoir. Here the water is sprayed high into the air to be purified. Sunshine playing upon the great fountain turns the place into a fairyland of dazzling white bedecked with shimmering rainbows.

mains, some of which are six feet across, cost millions of dollars.

But the reservoirs and aqueducts are the most picturesque parts of the great systems. New York City, for instance, has many reservoirs, the smallest of which nearly every New York boy or girl has seen on some jaunt in Central Park. The biggest of them is a hundred miles away, up in the Catskill Mountains. It is twelve square miles in area, and drains water from a territory as big as several counties. But the people of Los Angeles get their water in an even more exciting way. There are two aqueducts, one newly built, one a little older. The old one was once the longest in the world—some 235 miles, it carries water all the way from the Nevada Mountains, slipping through 142 tunnels on the way. The new one has 108 miles of tunnels. It brings water 242 miles from the Colorado River over a mountain range fifteen hundred feet high. Giant pumps driven by electricity from the Hoover Dam force the water over the mountains. It is the most costly water system ever built.

The reservoir lakes are all carefully guarded, many of them with wire fences, and while people may go fishing in them, nobody is allowed to use them for anything else. Indeed, the valleys that lead into the reservoirs are watched over for many miles, to see that the brooks and streams and rivers flowing through them are kept clean.

The Ills Our Water Can Bring Us

For, although we drink very little of the millions of gallons of water which flow into a city in a day, no one can tell which part he will drink, so it all has to be pure.

You might be surprised at the number of things that can go wrong with water. Perhaps it has so much ordinary dirt, or "silt," in it that it actually looks dirty. Or it may have an unpleasant odor. Or it may look

HOW A CITY GETS ITS WATER

Photos by N. Y. C. Board of Water Supply and Bethlehem C of C.

Here is one of the great horseshoe-shaped tunnels through which the pure waters of the mountain reservoirs flow to New York City. In the circle is the old waterworks building of Bethlehem, Pennsylvania, installed in 1754 and part of the oldest municipal system of water supply in America. Water power from an old mill dam operated the pump, and the pipes through which the water flowed were made of hollowed pine logs. Before that, water carriers had had to trudge up the hill carrying buckets on a yoke.

as clear as crystal, and yet taste like poison. Worst of all, it may look and smell and taste all right, yet carry in it deadly germs which will make people sicken and perhaps die. Fearful epidemics of cholera, diarrhea, and especially of typhoid fever, have swept through cities which are not watchful enough of their water supply.

How Scientists Purify Our Water

But modern engineers and scientists have found out ways to protect us from all these things. Of course, whenever possible, they get pure water in the first place; but even if that is impossible, ways have been found to purify whatever water must be used. In the past century, and especially in the past twenty years, marvels have been done with "settling tanks," filters, and purifying chemicals.

Think, for instance, of the problem of the cities that must take their water from the Mississippi River, which is brown with silt, or from the Missouri, which long ago earned the nickname of the "Big Muddy." The trouble here is not so much germs as plain dirt. So the cities first of all draw their water into huge basins or tanks and let it settle. The basins would fill up almost at once if they were not regularly cleaned out, for you can scarcely imagine how much mud is found at the bottom of them every day. New Orleans, which is at the very mouth of the great river, and has about the muddiest water in the world, every day cleans out of her settling tanks some five thousand tons of mud and sand. And yet, when the clear water has been drained away and filtered to make it pure as well as clean, there is nothing at all wrong with New Orleans water.

Sand Filters That Catch the Germs

Other cities have different problems. Philadelphia, for instance, which had one of the first waterworks in America (1799), must get its water from the Delaware and Schuylkill rivers, which by 1902 had become polluted (pŏ-lūt′)—that is, impure. So it was necessary to build enormous sand filters, and strain every drop that was pumped into the city mains. There are five of these filter plants, covering more than a hundred acres of ground and capable of giving the city four hundred million gallons of water a day. Recently Philadelphia has added an ozone plant to help in the purifying of her water.

Did you notice that those filters were called "sand filters" just now? One would never think that draining water through a bank of sand would clean the germs out of it. Yet ninety-eight per cent of them can be removed in that way. It was the Chelsea Water Company, in London, which first used a sand filter—in 1829. For a long time scientists could not quite see how such big things as grains of sand could strain out such tiny things as invisible bacteria. But after a while they discovered that every grain of sand was soon covered with a slimy coating, and that the bacteria stick in this slimy coat.

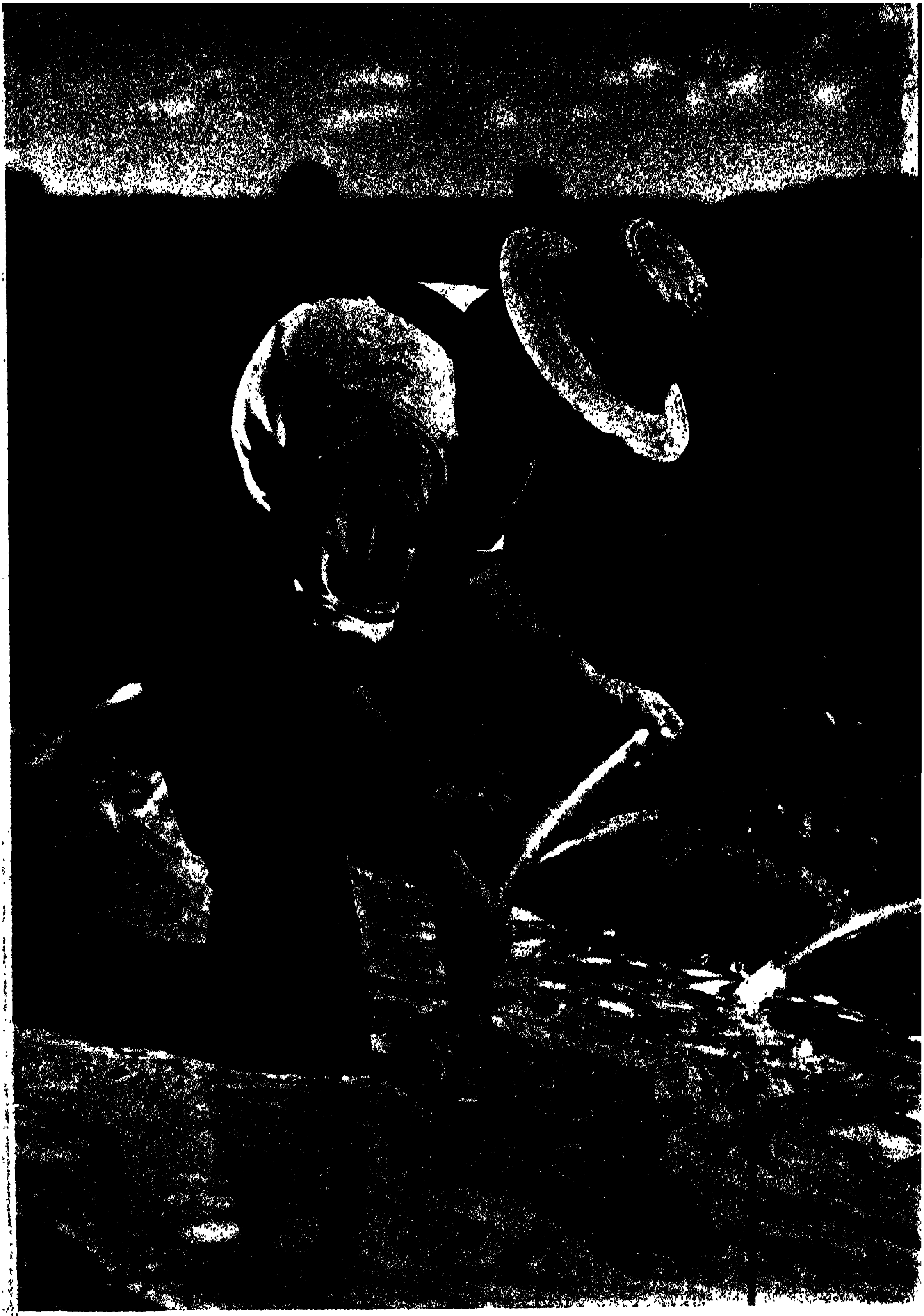
Adding Chemicals to Our Water

Often the engineers put chemicals into the water, either instead of filtering it through sand, or in addition to filtering it. Chlorine (klō′rĭn) is the main chemical germ-killer. It is much cheaper and works much faster than sand. Lime helps to settle the sediment copper sulphate (sŭl′fāt) keeps reservoirs free from the tiny water growths called algae (ăl′jē), and iodine is thought to keep people from having goiter. Chemists keep thinking of new and better ways to keep our water pure, just as engineers keep thinking of new and better ways to get it to us.

So the next time you turn on the faucet try not to take the splashing stream so much for granted. Think for a moment of peasant women with water jugs on their heads, and of the village pump, and of the public baths which are still the only way countless people have of keeping clean. Then think of the great man-made lake somewhere in the mountains, and the huge pipe that brings the water to you from it. and all the filters and pipes and pumps and "fixings" that make it so easy and so safe for you to turn that faucet on. After all that, you ought to enjoy your bath and your drinking water more than ever!

Courtesy Tennessee Eastman Corporation

These bright pellets are Tenite, one of our most useful plastics. It comes from the factory in this form instead of in sheets or rods or tubes or in the form of a powder. It can be made in any color, is very shiny, and may be transparent, translucent, or opaque. It will melt under extreme heat, and when manufactured into useful articles is either cast in a mold or extruded – that is, pushed out through an opening. It is very tough and so is used where a shatter-proof substance is needed. Though hard as aluminum it is only half as heavy by volume.



Courtesy Tennessee Eastman Corporation

Farmers, like people in many other occupations, are grateful to the chemist for various plastics. On this farm in the West, Tenite has gone to make the siphon tubes used for irrigation. The four-foot lengths are extruded, and bent to fit over the bank of an irrigation ditch. Because they are light and practically unbreakable they are easy to shift as row after row is watered. Transparent, they show wher there is a stoppage. Water flows easily through their smooth walls and will not rust or warp them. Sunlight will not crack them.

INDUSTRIAL CHEMISTRY

Reading Unit No. 26

MIRACLES OF THE CHEMIST'S LABORATORY

Note: For basic information not found on this page, consult the general Index, Vol. 15.

For statistical and current facts, consult the Richards Year Book Index.

Interesting Facts Explained

How the alchemist's dream has come true, 10–544
How the chemist combines elements to make new substances, 10 544-45
How the chemist helps the farmer, 10-545
Why the world no longer depends on Chilean nitrate, 10 546
How the farmer contributes to chemistry, 10-546
Why the Chinese tung nut is in great demand, 10–547
What transportation owes to the chemist, 10 548
What makes the kitchen a laboratory in disguise, 10–549-50
The story of plastics, 10–551-53
The thrilling drama of chemistry in medicine, 10-549

Things to Think About

What do we find out by chemical analysis?
What kinds of chemists are there, and what do they do?
What do we mean by "industrial chemistry"?
What can a chemist make from cotton?
What use is being made of the soybean?
How has chemistry helped in the field of medicine?

Related Material

What materials do chemists use to make our dyes? 9-304-7
Why was Venetian glass famous? 12–31-34
What use has been made of the "noble" gases that the air contains? 1 376-77
How many kinds of cotton plant are there? 9–28
What interesting facts do we know about bacteria? 2–12-21
How does a microscope work? 10-485-90
Rayon, 9–82

Leisure-time Activities

PROJECT NO. 1: Learn what you can about the chemist's "alphabet," 1–551, 10 544-45, 549

PROJECT NO. 2: Read the story of Louis Pasteur, 13-367-69

Summary Statement

With the great triumphs of modern chemistry, we know why the great Pasteur held the laboratory to be a sacred place, a temple set aside for the well-being and happiness of mankind.

Within one great chemical laboratory many separate experiments may be going on at the same time This small corner of a laboratory will give you an idea of how the men of science work with delicate instruments and complicated formulas to give us the marvelous things which make our lives healthier and more pleasant

MIRACLES *of the* CHEMIST'S LABORATORY

If You Need a New Fabric, a New Building Material, or a New Medicine, You Have Only to Tell the Chemist and He Will Go to Work to Create It for You

Ages ago our modern science of chemistry was born in the laboratory of the eager alchemist (ăl'kĕ mist) who was hunting a way to make gold It is a long, long time since men gave up that ancient search, and a great deal has been learned since then Almost unbelievably, the old alchemist's dream has come true Today our chemical laboratories are creating riches the ancients never dreamed the world contained The things made each year for the health and comfort and beauty of millions of people by chemical processes alone are worth billions of dollars What a dazzling vision for the blindly guessing alchemist, secretly at work in his smelly attic!

On other pages of these books we have told you what the science of chemistry is and the laws it obeys The chemist makes it his business to study the substances found in our universe He is not so much interested in an object like a storage battery, for instance as he is in the lead, hard rubber, and sulphuric (sŭl fu rik) acid of which it is made And the chemical changes which take place in the battery when it is put to use are still more important to him

Now you will remember that the chemist works with only ninety odd elementary substances Just as a novelist juggles the twenty six letters in our alphabet to make endless words and sentences, the chemist

combines his elements. Sometimes he reproduces what Nature has already made, and sometimes he makes entirely new substances.

A Visit to a Research Laboratory

Chemistry touches our life at every point, yet it has so many special branches that no one man can know all of it. In a single research laboratory where industrial chemicals are manufactured, hundreds of chemists will be hard at work on their separate jobs. In the analytical laboratory they break down all the materials used in the plant in order to discover their strength and purity. Next door, in a wilderness of complicated apparatus, men are busy building up complex substances by putting other substances together. This is called synthetic (sĭn-thĕt'ĭk) chemistry, the source of a staggering array of new compounds. The synthetic chemist skillfully adds or subtracts atoms until the structure of the molecules (mŏl'ĕ-kūl) meets his demands. He takes extreme care how he puts his elements and atoms together, for the final combination, like the words of the novelist, must have real meaning. He may be performing a special task for Man, the master, or he may be testing some strange new compound to find what it will do.

Some Modern Wizards

Farther along in this same plant are the physical chemists, using the laws of chemical behavior to measure the heat set free in a chemical reaction. Close by is the electrochemist, who studies the relationship between chemical changes and electrical activity. This man knows how to take from impure copper unbelievably small, though very valuable, amounts of gold and platinum. Then there is the biological chemist, who studies the processes of life itself, and the sanitary chemist, who carefully analyzes our water supply so that he can make it safe for drinking as well as for use in boilers and dye vats. And these are only a few of the men and women we should see.

Outside the research laboratory the chemical engineer, trained in both chemistry and engineering, carries out on a large scale the processes which the laboratory chemist developed in his little glass tubes. Besides the chemical industry itself, which manufactures chemicals of all sorts, there are a good many "process industries"- that is, industries which involve the chemical changing of matter into some more usable form. Petroleum and sugar refining; rubber, gas, cosmetics, and explosives manufacture; the production of alloys (ă-loi') combinations of two or more metals- and plastics; the paint, cement, artificial silk, and brewing industries all make use of chemistry. Chemistry as we know it is a modern science, but there are many fields in which the art of chemical manufacture has been handed down time out of mind. This has been true of glass manufacture and the smelting of certain ores. We are now able, however, to improve these old arts by making use of modern knowledge. Our civilization owes most of its luxuries and comforts to the chemist, to say nothing of many vital necessities.

The Farmer's Debt to the Chemist

Although they seem at opposite poles from each other, the modern farmer would be lost without the chemist at his side. When his corn stands higher than his neighbor's and his pigs are fatter, you may be sure he has called on the chemist for help. When one field of cotton is full-blown, white, and fluffy and the next one is dark with unopened, weevil-infested bolls, there is a simple explanation. The first farmer has followed scientific advice. He has had his soil analyzed by the government chemist to find what it lacks of the elements necessary for proper plant growth. Then he has supplied them in the form of suitable fertilizer. The food for his livestock has been recommended by a scientist who knows the chemistry of food and nutrition.

Elsewhere in these books you have learned how the soil is made and have found that it contains certain minerals that are necessary for plants to grow properly. Nature long ago fell far behind in the task of putting these elements back in the soil after they were taken away. The principle chemicals needed by plants are nitrogen (nī'trô-jĕn), potassium (pô-tăs'ĭ-ŭm), and phosphorus (fŏs'fôr-ŭs), but it is not enough

simply to put them in the ground. We find that they must be provided in a form which the plants can use, and that other elements, like manganese (măng'gȧ-nēs), copper, and magnesium (măg-nē'zhĭ-ŭm) are also important. Our forefathers knew the value of manure, which provides nitrogen in the form of ammonia, one of the forms which plants can use. Slaughterhouse waste also puts back in the earth various mineral substances which the animals got from the plants that in their turn took up those substances from the soil they grew in. When the waste decays, another crop of plants can take up those substances- and then more animals can feed on the plants! And so the cycle goes on.

Putting the Air Itself to Work

Our ancestors also learned the value of letting land lie "fallow" or idle from time to time; or better yet, of planting it to crops of what are known as legumes (lĕg'ūm) —beans, peas, clover, and alfalfa (ăl-făl'fȧ) —whose roots bear thriving colonies of millions of bacteria (băk-tē'rĭ-ȧ), those plant forms so tiny that they can be seen only under the microscope. The bacteria on the roots of such crops as peas and clover take nitrogen, a gas, from the air and "fix" it in the soil in a form the plants can use. For plants cannot take nitrogen directly from the air. It must be "fixed" that is, chemically combined with some other substance.

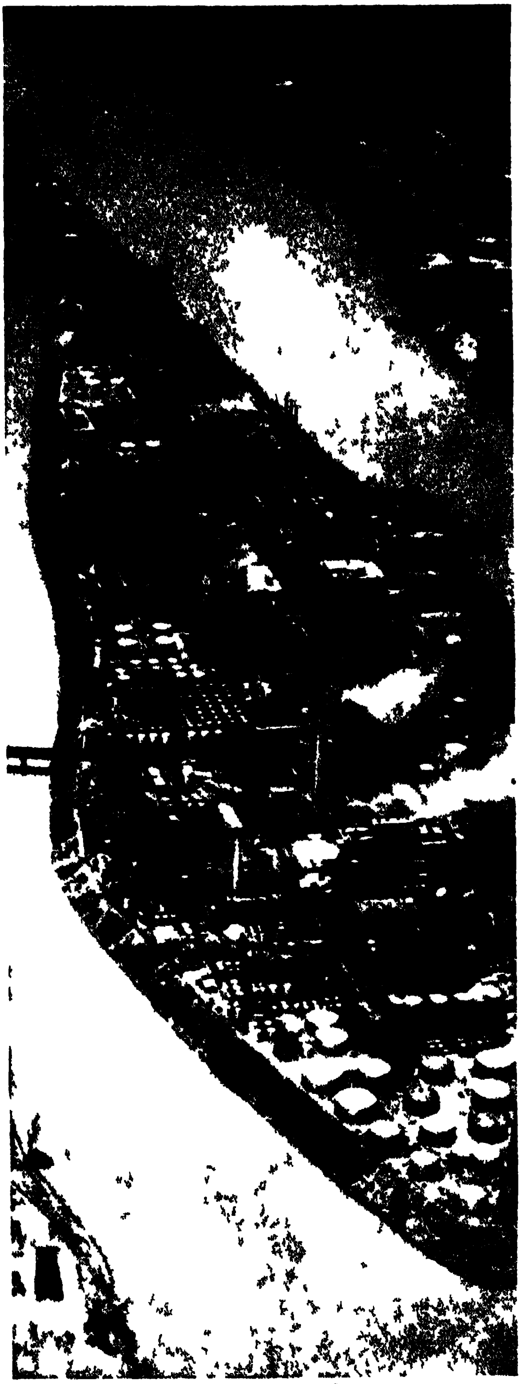
When these natural methods did not put enough nitrogen back in the soil, the careful farmer of the past added it in the form of Chile saltpeter (sôlt-pē'tẽr) –that is, sodium nitrate (sō'dĭ-ŭm nī'trāt) from the enormous natural deposits in a very dry section of Chile. Then a German scientist, Fritz Haber (hä'bẽr), discovered how to make saltpeter from the ammonia which resulted when nitrogen in the air was "fixed" with hydrogen gases. Haber's process makes use of the 22 million tons of nitrogen in the air over each square mile of the earth's surface. This is the source of the ammonia we use in our refrigerating plants and in our kitchens. America's great need for potash to raise foodstuffs led to a search for new sources that ended in the dry bed of Searles Lake in California, which provides us now with large quantities of this valuable fertilizer.

Chemical Weapons against Pests

Louis Pasteur (pȧs'tûr'), whose story is told in these books, was one of the earliest chemists to help agriculture. Following him other chemists have given the farmer the blasting powder to clear his land, weed killers such as 2, 4D which save him hours of hoeing, ripening agents to add color to his product and so help to market it, insect and fungus killers- Paris green, formaldehyde (fôr-măl'dē-hīd), nicotine to poison weevils, insects, grubs, and fungus spores. Probably one-fifth of the world's crop is destroyed by such pests, in spite of the billions of dollars spent by the American farmer annually in his war on them. You may draw your own conclusions as to the size of the world's crop if the farmer did not have the chemist to help him in this war.

Interestingly enough, the farmer in his turn makes a notable contribution to the work of the chemist. The large surplus of foodstuffs in a world that did not use them was driving the farmer to bankruptcy when far-sighted chemists and industrialists started what they called the chemurgic (kĕm-ûr'-jĭk) movement. This was a plan to use the farmer's produce in industry. The farmer and the chemist work together, with the result that the farmer can look forward to a steady cash income from what he grows for the chemist.

Already a good deal has been done. One great chemical manufacturing company uses millions of pounds of cotton every year to make rubber-coated fabrics, artificial leather, and various patented fabrics. It uses the "linters" short cotton fibres attached to the seed, and formerly thrown away in making imitation ivory and silk, photographic film, and plastics. This same company produces paints and varnishes, linoleum, and printers' inks from the oils pressed out of vast crops of soybeans, flaxseed, cottonseed, and tung nuts. To meet the chemist's demand for the tung nuts, trees have been imported from the Orient and



Courtesy Union Carbide and Carbon Corporation

Here is a portion of one of the largest chemical plants in the United States. It covers the whole of this island and spreads several miles along both river banks. Vast laboratories, factories to make chemicals, power plants, storage tank farms, coal yards, freight yards and sidings, and huge river barges are all vital to the chemical industry which serves us.

planted in the Southern United States.

Corn is another crop for which the chemist has found dozens of new uses. It yields such products as starch, adhesives, "dry ice" (the solid form of a gas called carbon dioxide (dī ŏk'sīd)) and glucose (glōō'kōs), which may be turned into either rayon or table sirup. One company uses up every year the yield of more than one and a half billion acres. Corn is coming to be still more important as a source of the industrial alcohol which can replace petroleum as a fuel. It is the starting point for a long line of chemical products like "canned heat" and ether.

Perfumes from a Lump of Coal

The list of the chemist's miracles is endless. Forests give him valuable materials. A single big company can swallow up thousands of tons of wood pulp in its annual output of rayon, cellophane (sĕl'ō-fan), and other products. In addition, millions of pounds of turpentine and rosin, from thousands of acres of pine timber, go into such common needs as paints and brushes. From the ugly stew of wood pulp the chemist brings beautiful rayon, which he colors with bright dyes created from coal tar. Coal tar itself becomes a Jack Horner pie under the hand of the chemist. From it he pulls such plums as aspirin, enchanting perfumes, the explosive called T.N.T., and the wonderful sulfa drugs which have put an end to many dreadful diseases. Skim milk had little commercial value until it was touched by the magic of chemistry. Then lo! its solid part, called casein (kā'sē-ĭn), appeared in the forms of glue, plastics, and fabrics.

Except for agriculture and construction, the making of automobiles is our biggest industry, but it could not produce fast, cheap, and beautiful cars without the aid of the chemist. Every part of the car, from its chassis of alloy metal to its lustrous finish, has depended on the genius of the laboratory in some way. "Anti-knock" compound, lead tetraethyl (tĕt'ra-ĕth'ĭl), added to the gasoline diet of the car's engine in as small a proportion as three teaspoonfuls to a tankful, makes it possible for us to get more power and longer mileage with less fuel.

and a smaller engine. Thanks to the alloys given us by the chemist, we have not only more economical cars, but also faster, safer, and more luxurious trains and ships. And can you imagine making airplanes to fly faster than the speed of sound without the light, tough aluminum and magnesium alloys which are one-third and one-half the weight of steel?

Chemistry Comes to the Builder's Aid

Our construction industry, the country's second largest, is founded on millions of barrels of cement and millions of tons of steel. Each of these barrels and tons is the result of chemical transformations. Glass, always important for windowpanes, is now being used in both homes and skyscrapers in the form of glass bricks, which are not only good insulators but are so strong that it is hard to break them. More than that, the chemistry of glassmaking has given us plate glass so tough that it is flexible, and will not shatter into sharp pieces. Every day in our kitchens we use glass articles which do not break when they are popped out of the refrigerator straight into the oven. The kitchens themselves are clean and gay with tiles and porcelains, lacquers and enamels which are better than the older, more costly sorts.

What Are "Heavy" Chemicals?

From all that we have said you will see that chemical processes are at work in many plants which on first thought would hardly seem to be concerned with chemistry at all. Of course the manufacture of chemicals as such is in itself a vast industry. The products are of all kinds. For instance, there are the "heavy," or general-utility, chemicals, such as sulphuric acid, nitric acid, and sodium carbonate (kar'bô-nāt). Then there are the synthetic organic chemicals, such as dyes, drugs, and solvents—substances that can dissolve other substances. Still other chemicals, like chlorine (klō'rĭn), sodium, and magnesium are made by electrochemical processes. One great chemical plant may make hundreds of products by combining a few simple substances in a variety of ways.

Photo courtesy B. F. Goodrich Company

Before any of the things we ask the chemist to create for us can be produced in the factory, they must first be made and tested in small quantities in the laboratory. Because each new project must have its own treatment, the chemist often uses homemade apparatus. Later, engineers will design and build large-scale, permanent copies of the laboratory equipment.

Our great light and power industry makes use of chemistry in a number of ways. Most of our electric power comes from steam power, which in turn we get from the energy set free when the carbon of coal combines with the oxygen of the air in other words, when coal burns. Naturally, the steam boiler is an important part of all this. The chemist keeps the steam boiler under close control, analyzing flue gases so he can get the most efficient service from the fuel. Since the water we drink would upset the surprisingly delicate stomach of this machinery, the chemist prevents scaling and corrosion of the boiler's sides by treating the water chemically.

Each Engine Has Its Proper Diet

Each turbine, diesel engine, and smelting furnace has its own proper fuel and lubricant, and it is the business of the chemist to choose the right one for each. In the matter of materials, also, the electrical engineer has been greatly helped by the chemist. When night would fall, both city streets and country highways glow with the chemist's handiwork. Neon filled tube lights, sodium vapor lamps that in efficiency approach the cold light of the glowworm, and of course our gas-filled electric light bulbs with their tungsten filaments all these chemistry has created to help man push back the darkness from his busy life. The chemist has helped us speed our thoughts from man to man by the telephone, telegraph, radio telephone, and television radio. Without the special materials which go into inductances, resistances, magnets, cable sheathings, and so forth, the electrical engineer and the physicist could not have made those marvels which dwarf space into nothingness.

In the same way, chemistry has helped to pass our thoughts to future generations by the service which it has given to the world of print - to newspapers, magazines, and books. We have from the chemist paper processed from rags, wood pulp, and sulphite liquor; it has been bleached by chlorine and bears the imprint of chemical inks applied by electrotype.

In the story of how a city gets its water you have read how chemistry is used to supply us with pure water for drinking and washing. But even after this water has flowed out of the faucets and down sinks and drains, it is still the concern of the chemists. The sanitary engineer uses chemistry to treat sewage so that it is rendered harmless. The modern garbage disposal plant recovers enough useful materials to pay for its operations. Modern cities can now avoid typhoid and other epidemics.

The Great Work of a Great Chemist

The tale of chemistry in medicine is a thrilling drama of war against death from disease and accidental injury. In this combat the chemist has added his strength to that of the physician, the biologist, and the bacteriologist (băk'tē-rĭ-ŏl'ō-jĭst), whose business it is to study germs. Those men of science have won brilliant victories. Here again it was Louis Pasteur, that master of chemical science, who led the attack in one of the great advances against the enemy when he snatched the instruments from the soiled hands of ignorant surgeons and passed the tools through sterilizing flames. His fellow scientists only laughed at his experiments to prove that infection takes place through tiny, living things too small to be seen by the naked eye. But today we hail him as a great savior. On other pages we have told you of his work in combating rabies (rā'bĭ-ēz). It has been said that in all the work chemists have done, his "was the most signal and sweeping triumph of chemical knowledge deliberately applied to the redemption of mankind from disease and pain."

A Scientist's Heroic Experiment

His victory inspired other workers, and pointed out the way to be followed in checking such ancient ravagers as cholera (kŏl'ẽr-ȧ), lockjaw, diphtheria (dĭf-thē'rĭ-ȧ), typhoid fever, bubonic (bū-bŏn'ĭk) plague, and scarlet fever. The quiet, magnificent heroism of these men of science was shown by Paul Ehrlich (ĕr'lĭK), the physician and chemist who worked 605 experiments before he produced a dyelike substance which he hoped would kill one of the deadliest blood

diseases. It worked with chickens and rats, but would it work equally well in human beings? There was only one way to find out —so Ehrlich tried it on himself. When the experiment on himself proved successful, he named his new remedy "606"– because it was the 606th substance he had tried.

Our many germicides and antiseptics have been given us by men who often were as unselfish as Ehrlich. They have supplied the physician with various anesthetics (ăn′-ĕs-thĕt′ĭk), those merciful drugs which still our pain and allow our surgeons to perform delicate operations. They have developed glandular products designed to make up for various bodily deficiencies. One of these is insulin (ĭn′sû-lĭn), prescribed for diabetes (dī′à-bē′tēz), and another of them is adrenalin (ăd-rĕn′ăl-ĭn), which has proved a valuable heart stimulant and preventive of bleeding. New narcotics have been found which, like opium, relieve pain and put the patient to sleep, but which are less likely to be habit forming. There are powerful remedies to bring down a fever, and analgesics (ăn′ăl-jē′sĭk), like aspirin, to reduce pain and quiet the nerves. And we should not forget our new knowledge of the part played by vitamins. It is easy to guess at the commercial importance of drugs when we are told that every year the American public uses a million dollars' worth of aspirin alone.

Chemistry at Work in the Kitchen

No one needs to look far to discover that in our homes a great many chemicals are put to daily use. The kitchen is really a laboratory in disguise. On laundry day, soap, blueing, bleach, and starch are used to turn out smart-looking clothes. On baking day the housewife works with bleached flour, dried yeast or baking powder, vegetable colorings, pyrex dishes, concentrated milk, and a host of other chemically produced items. She heats her baking oven by artificially made gas, and lights it with a safety match. On the kitchen floor is sleek linoleum and in the drawers are stainless steel cutlery and silver-plated ware. All these products have been made with the help of the chemist.

Woolens without Wool

So it is not surprising that the chemical industry in the United States has grown to vast proportions. It and certain allied industries manufacture products worth about one-tenth of all the products made annually in the United States, which has the largest chemical industry in the world. And this gigantic industry is growing as the years go by. For as we use up the valuable resources that Nature gave us, it falls upon the chemist to find new materials. At the same time, he must try to find ways to save the resources we still have, and to use them in the most efficient way.

Countries less well off than the United States in natural resources are putting forth tremendous effort to bring their chemical industries to a point where the nation will no longer need to depend on other countries for supplies. German chemists have learned to make from their abundant coal the oil which their country lacks. Italy does not have sufficient wool, so her chemists have developed a wool substitute from the solid parts of milk. In such ways chemistry accomplishes wonders that seem nothing less than miracles. When its products, such as artificial silk, fertilizer, and coal tar dyes, are turned into munitions, chemistry becomes a cruel master, as does fire when it gets out of control. But when it is properly used, it is a marvelous servant, tirelessly making over the very stuff our lives are made of.

No wonder the great Pasteur held the laboratory to be a sacred place, a temple set aside for the well-being of mankind, dedicated to producing a race of men that shall be "greater, stronger, and better" than the men who went before.

Photo courtesy Monsanto Chemical Corporation

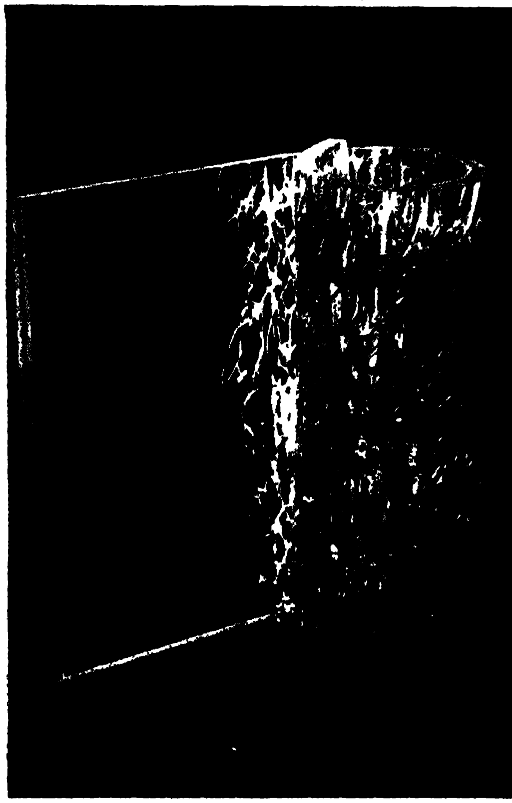


Photo courtesy E. I. du Pont de Nemours and Co.

The fluffy white substance this workman is peeling off the cylinder is vinyl butyral, a plastic used to make safety glass like the piece at the right. The opaque plastic turns transparent when it is compressed between two sheets of glass. Even though the glass may break, it will not fly apart into sharp, jagged pieces.

The CHEMIST'S LATEST MIRACLE

Glass Cloth Stronger than Aluminum and Gears That Need No Grease Are among the Wonders We Owe to Plastics

It took an explosion of the sun and a hundred million years to cool the fragments in order to create our metals. There were less than a dozen of them in all to begin with, and as civilization developed, men drew heavily on the stocks of these few. Nature could not keep pace with the demand. So chemistry has been busy during the past century changing Nature's products to make them serve us better. In answer to the challenge of modern living, chemists produced what we call plastics—those brightly colored, tough materials which store our food and help to clothe and shelter us. The most unlikely materials go into their making and amazing properties have been built into them.

All these plastics are largely built up out of a useful element found in vast quantities throughout the universe. It is called carbon and it helps to make up the bodies of all plants and animals. It is found in large quantities in coal, coal tar, and petroleum, because ages ago those substances were made out of trees and other plants.

When the chemist sets out to make a plas-

tic he starts with carbon-bearing materials known as resins. He treats these resins with chemicals. When heat and pressure are applied to the resin mixture, a plastic is formed. Resins are found in nature, but they can be made up in the laboratory by combining such substances as coal, air, water, sulphur, limestone, and petroleum in giant pressure cookers. Of those substances coal is the most important by far. It is the keystone in the production of most plastics.

When you hear someone say, "It's a plastic," you know what is meant, but it is difficult to say just what a plastic is. We apply the term to manufactured substances that will flow into a given shape which they will keep after being properly treated. Glass, which man has made for centuries, is in reality a plastic, but it is not made up out of materials derived from living things, as our modern plastics are.

Billiard Balls That Exploded

The very first plastic in the modern sense was the common substance known as celluloid. It was invented by a young man in Albany, New York a printer named John Wesley Hyatt. He had heard of a billiard ball manufacturer who stood ready to pay ten thousand dollars to whoever could find a substitute for expensive ivory. One day Hyatt came on a bottle of collodion- we sometimes call it "new skin"—which had hardened where it had spilled. He was no chemist and he did not know that collodion's principle ingredient is nitrocellulose, or guncotton. He was blissfully unaware that he was knocking around one of the world's most dangerous explosives. He submitted to high temperature and pressure his mixture of nitrocellulose, powdered camphor, and red coloring. When the mixture had hardened he had celluloid for the balls, but he got no prize. For when the balls were hit too hard they exploded. Further experiments tamed celluloid of its violence and made it a good substitute for amber, ivory, and pearl. But of one vice it could not be cured—it took fire very easily.

Perhaps it was an accident or perhaps Adolf Spitteler was joking when, twenty-two years later, he combined sour skim milk with formaldehyde, a liquid derived from wood alcohol. He found he had a white, hornlike substance, hard and shiny, which could be used to make good buttons. This was known as casein (kā'sē-ĭn) plastic, "casein" being the name of the solid part of skim milk. It is high in protein, that element in our food that goes to repair our bodies. Casein plastics come from the factory in rigid sheets, rods, or tubes, and they will warp and crack just like the protein plastics made from soybean and corn gluten. But they may be made in nearly any shape and color and so are very useful.

Bakelite for Scores of Jobs

Nearly twenty more years went by before we had a really serviceable plastic. In 1909 a Belgian-American chemist, Leo Baekeland (bāk'lănd), was seeking a substitute for shellac, an expensive substance used in making phonograph records. He produced a plastic from formaldehyde and phenol (fē'-nōl), or carbolic acid, which comes from benzine, a liquid derived from coal. This plastic, named Bakelite after its discoverer, was not useful in making records because it could not be remelted, once it had set. But this very stubbornness under heat, together with the fact that it is solid, cannot be dissolved, and that it will not conduct electricity, made it just what the manufacturers of electrical insulators needed. Bakelite and other phenolic (fē-nōl'ĭk) plastics serve more purposes than any other plastic. Because they are hard, they serve well in the gears of motors and are excellent for making plastic-bonded plywood. Moreover, they are cheap and easily worked, since they come from the factory in the form of molding powder which needs only to be melted to a sirupy liquid to be molded to almost any shape.

The next plastic to be invented, called cellulose acetate (ăs'ē-tāt), was a "thermoplastic"--that is, it can be melted and remolded, as "thermosets" like Bakelite cannot be. Cellulose acetate, like celluloid, is made of the substance called cellulose (sĕl'-ū-lōs), which forms the bulk of plants and is high in carbon. Cotton fibers are treated

with acetic (ȧ-sē'tĭk) acid, derived from the calcium resulting from burning limestone with coke. It is the acid we find in vinegar. Acetic anhydride also goes into this plastic. Because it is tough and transparent and will take beautiful colors, cellulose acetate is excellent for small objects and decorative touches. When it is dissolved in a chemical called acetone (ăs'ē-tōn) it can be spun into acetate rayon.

Fifteen Main Types of Plastics

And now a procession of varied plastics came rapidly into being. There are thousands of them, but they all fall into some fifteen main types. Some depend on cellulose, as do ethyl (ĕth'ĭl) cellulose and cellulose acetate butyrate (bū'tĭ-rāt), both sturdy enough to withstand a sharp blow. Then there are the alkyds (ăl'kĭd) derived from coal. They are thermosetting and moisture-proof, so they are used to make richly colored paints, varnishes, and lacquers that are tough, quick-drying, and able to resist weather. Paints like these have revolutionized the paint industry.

The pretty urea (ū-rē'ȧ) plastics are very much like the phenolics, but they do not resist wear so well. They make good tableware, buttons, and other small objects, and are the result of combining formaldehyde and urea, a substance derived from ammonia. Better tableware is made of melamine (mĕl'ȧ-mēn), the hardest plastic. Then there is a large group of thermoplastics called vinyls (vī'nĭl). These are made by mixing acetic acid with either natural gas or with acetylene (ȧ-sĕt'ĭ-lēn) gas, a product of coal and limestone. One of the vinyls is the principle plastic used in making safety glass, which is built up of alternate sheets of glass and plastic. Another goes into adhesives, inks, and metallic paints. And still another is the rubberlike substance which comes in many charming colors and is used for raincoats, shower curtains, and the like.

Vinilidene chloride (vĭ-nĭl'ĭ-dēn klō'rĭd) often replaces rubber, copper, and steel in pipes and flexible tubing, for it is transparent, flexible, and water-proof, and can withstand a severe pull. This plastic makes strong ropes and cables and stout fish lines.

Among the most expensive plastics are the acrylics (ȧ-krĭl'ĭk), beautifully transparent and very rigid. Two of them we know as Plexiglass and Lucite. Thanks to their charming colors they are usable in objects ranging all the way from furniture to contact lenses. Petroleum, their chief ingredient, can be refined to produce a chemical called ethylene (ĕth'ĭ-lēn), to which air, water, and acetone are then added.

Lightest of all the plastics are the polystyrenes, those beautifully transparent products of coal and petroleum. Because of their low price these plastics are in great demand. They do not conduct electricity and they can be told from other plastics by their metallic ring.

Nylon May Become Cloth or Gears

Perhaps the best-known, and certainly the toughest, of the plastics are the nylons, which make light, durable clothing for us. For our machines they make gears and bearings which run noiselessly and need no grease.

One of the most interesting uses of plastic is in the making of "plastic-bonded plywood." Like safety glass, this is what we know as a laminated substance—that is, it is built up of thin sheets fastened together with an adhesive. The sheets of wood are piled so that the grain of each new layer lies at right angles to the one under it. Then those sheets are bound together with plastic under great heat and pressure in huge molds. As the plastic seeps into the pores of the wood, a new substance is created. For its weight, plywood is stronger than steel. It is no wonder that we find it in the bodies of some of our fastest airplanes.

It is hard to say where the chemistry of plastics will end. New formations and applications are brought to light every day. For example, it has recently been found that glass cloth dipped in resins will make a material thirty percent stronger than aluminum, even though it is only two-thirds the weight of that metal. Of one thing we can be certain: the chemistry of plastics is leaving Nature far behind.

Reading Unit No. 27

Note: For basic information not found on this page, consult the general Index, Vol. 15.

For statistical and current facts, consult the Richards Year Book Index.

Interesting Facts Explained

When almost no one could afford to own a book, 10-555
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Things to Think About

How far back does the history of libraries go?
What special departments do our libraries have to-day?
What are "bookmobiles"?
What do modern libraries do for children?
How can we feel at home in one of our libraries?
What do the call numbers on books mean?

Picture Hunt

What are the most cherished possessions of the Library of Congress? 10-555
How much money does Columbia University spend each year on the library? 10-559

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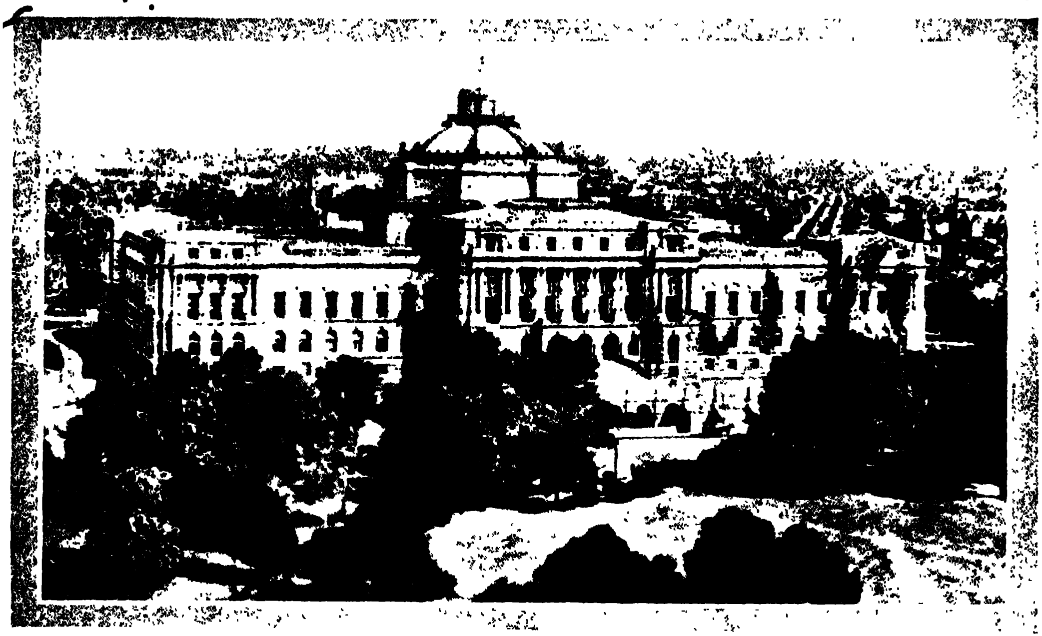
Leisure-time Activities

PROJECT NO. 1: See how the Dewey system works in your local library, 10-561-62

PROJECT NO. 2: Make call numbers for your own books, 10-562



The Library of Congress at Washington, D. C., has one of the world's greatest collections of books, manuscripts, and prints. When the library was established in 1800 the books were kept in the Capitol. There the first collection was destroyed by fire when the British attacked Washington in the War of 1812. Later, in 1897, the collection became so enormous that the great building shown above was erected to house it. But even that was not big enough, for recently an annex has been added. It can hold ten million books and also have room for the Copyright Office, which is housed in the library. Cherished possessions of the library are those important documents, the Declaration of Independence and the Constitution of the United States. Visitors may enter the building on any day except Christmas or the Fourth of July. To all intents and purposes this is a national library.

LIBRARIES *and* HOW *to* USE THEM

Here You Will Learn How We Came to Have Those Great Storehouses of Books to Which We Owe So Large a Part of our Modern Enlightenment

WE HAVE grown so used to reading books that we can hardly imagine what the world would be like without them. Yet there was a time when almost no one could afford to own a book. The bulk of the people could not even read and write. Ideas were passed from man to man by word of mouth, and information—or misinformation!—was passed on hardly at all. Children were taught to farm or build or bake or brew but there education ended.

To-day the inherited knowledge of all the ages lies open to almost anyone who can read and write. As you sit in one of our great public libraries you are surrounded by all that the finest minds of our race have been able to produce. You would think it a thrilling privilege to shake the hand of certain of these great ones, and perhaps exchange a few hurried words. How much more of a privilege it is to find on these shelves the greatest thoughts of these great men, their deepest and most sacred convictions, all set down in language as clear and forceful as the authors could command. Just by opening the volumes, you are admitted to the society of the choicest spirits the earth has ever seen. All this we owe to our modern libraries.

The history of libraries is long and interesting. It goes back far beyond the invention of printing—and of course far beyond the development of the book as we know it to-day. Some learned men say that there

are traces of libraries existing as early as 3,000 B.C. We know for certain that there was one in Babylonia in 2,000 B.C. But how strange it would have looked to us! The "books" were clay tablets stamped with queer-looking wedge-shaped marks and baked in the sun. The earliest libraries contained, not stories or poems or scientific matter, but important political and religious records. In other words, they were archives (ärk'īv)—that is, collections of documents of state. Such libraries were kept by priests and housed in a temple.

The Greatest Library of Old

In 600 B.C. there were important libraries in Nineveh (nĭn'ē-vē) and Greece; and about 300 B.C. Ptolemy I (tŏl'ē-mĭ) established the famous library at Alexandria in Egypt, the greatest in the ancient world. It suffered sadly at the hands of various conquerors, and in 640 A.D. was entirely wiped out by the Arabs. By the fourth century A.D. Rome had twenty-eight public libraries, and the fine new city of Constantinople boasted one founded by the emperor C istantine. War and invasion wiped out these valuable collections, though some of the material, which was carried away and scattered fai and wide, has been recovered and is preserved in our great modern collections.

During the storm and stress of the Middle Ages it was the monks--the only learned men of their day—who collected books and took care of them. They painstakingly copied their treasures by hand and decorated them with drawings and pictures so beautiful that kings were proud to own them. Such "manuscript" books were given honored places in cathedrals and palaces as well as in monasteries, and many of them are the chief treasures of some of our great libraries to-day.

The Famous Vatican Library

The Vatican (văt'ĭ-kăn) Library at Rome - largely given over to manuscripts is an outgrowth of one of these early libraries. It was begun in 1295, and to-day has one of the greatest collections of manuscripts in the world--that is, of works that are in writing rather than in print, like our modern books. Other great libraries founded during the Middle Ages are the Library of the Sorbonne (sôr'bôn')—established in 1253 and now a part of the University of Paris - and the Laurentian (lôr-rĕn'shĭ-ăn) Library, established at Florence in 1571. Among early university libraries were the ones at Oxford (1327), at Prague (1348), and at Heidelberg (1386). The Bodleian (bŏd-lē'ăn) Library, one of the greatest modern collections, was established at Oxford University in 1602.

In the early days of our own country, libraries were mostly collections of books in private families. Dr. Cotton Mather of Boston had the largest of these collections; in 1700 it contained about three thousand volumes. But most private libraries had only a few treasured volumes--for few people could afford to buy books. Generous owners would of course lend their books, but naturally only to friends. Because large numbers of people thirsted for knowledge group ownership of books gradually came about. Harvard College established a library for its students in 1638, and toward the close of the century William and Mary College in Virginia organized one. During the following century Yale, Princeton, Columbia, and Dartmouth all founded college libraries. To-day many of our universities have very fine libraries, and all colleges have serviceable collections.

Our Early Colonial Libraries

Shortly before 1700 Dr. Thomas Bray came over to this country as a missionary. He saw the need of books and went about the task of establishing parish libraries in Maryland and elsewhere. One of the first was the library of Trinity Parish, in New York (1698). The Bray libraries were intended for clergymen, but they were often used by other people and so are sometimes called public libraries. Various dates are given for the first public library in America. We know of one that was set up for the Indians in Henrico (hĕn-rī'kō) County, Virginia, in the 1620's; and 1653 has been given as the date for the establishment of a public library in the Town House in Boston.

As education spread, the little collections we have described failed more and more

Photo by the New York City Public Library

In the reading room of a modern library you will find broad tables on which to spread your books, comfortable chairs to sit in, and good reading lamps to read by. And perhaps best of all over this room devoted to the pleasure and learning that is to be found in books, quiet will reign.

pitiably to meet the needs of the people. Then those who could afford it began to form associations which should buy books for the use of the members. This was a big step forward, even though only stockholders or annual subscribers could borrow the books owned in this way

Benjamin Franklin's Library

One of the earliest and most memorable of those associations was founded by Benjamin Franklin. In 1731, when he was still a poor man, he brought together a group of some fifty young tradesmen in Philadelphia and helped them organize to buy such books as they had money for. Gifts swelled the collection, and Franklin and his friends soon had a thriving little library. Another interesting library of early days was the "Revolving Library" of York and Kittery, Maine. Its name came from the fact that the entire library was sent from parsonage to parsonage in the three parishes in York and Kittery. In this way all the people in the district could visit it.

Another famous library, sometimes called the forerunner of our public libraries to-day, was the "Coonskin Library" (1802) at Ames, Ohio. Its history is very interesting and very revealing of the difficulty people had in getting books along the early frontier. The pioneers in the vicinity of Ames met together one day to discuss the building of roads, one of the most important steps in founding a new community. And at the same meeting they threshed out the problem of getting hold of a few books. They had no money, but each of them had a willing pair of hands and of course each had a gun. Now the woods were full of bears and raccoons whose skins would bring a tidy sum in the cities east of the mountains. Why not let each man donate a number of skins to be sent to Boston and turned into money to buy books? Before long a pack horse brought out some sixty volumes and the Coonskin Library was well started. It was fittingly named for the skins that had gone to its purchase.

The First Free Libraries

A good many library associations sprang up all over the country, but in spite of them the needs of the majority of the people were not met. There was a growing demand for real public libraries, which should be supported by the state and free to all. The first response came in New York State, where school district libraries were set up (1838) in the district schoolhouses, to serve not only the schools but all the people in the neighborhood. The plan spread to other

states and for a time worked very well, but the demand for books kept growing and soon something more was needed. Before long the public library as we know it to-day was actually launched in Massachusetts when the state passed the first act (1848) authorizing a municipality to tax itself for the support of a free public library. Under this act the Boston Public Library was opened in 1854. This was the beginning of a movement that soon spread over the country.

The Public Library of To-day

Since then the idea of what a public library should be has never ceased to grow with the changing times. Our public libraries of to-day have special departments in such subjects as art and music, visual material, and patents and documents. Branch libraries, traveling libraries, and deposit stations take the books close to the homes where people live and the business districts where they work. Children's departments and work in the schools now are a large part of a library's service.

Most of the large city libraries have branches scattered through the city. In them are interesting and useful books under the care of trained librarians. Sometimes these branches have charge of sub-branches, where a small collection of books under a trained librarian is open to the public for a few hours each week. Sub-branches are often set up in park field houses, in outlying community centers, and occasionally in church recreation houses. Through a branch library one may get books from the main library; in the large cities library trucks make daily deliveries of books requested by the various branches. Naturally these convenient branch libraries are very popular, and often carry a large percentage of the circulation of books in a city library system. Deposit stations are mostly collections of books set up in business houses, churches, clubs, and other centers for circulation within the group in whose hands they are placed. They are usually administered by an employee of the institution that houses them.

Rural districts too can borrow good books, sometimes from the state library and sometimes from the county or township. State libraries may send out traveling libraries, package libraries, or deposit libraries that are placed in a home or a school in a given district. County and township libraries, too, may often get books from some large city library that is not too far away. Sometimes a city and county will combine in serving the people.

"Bookmobiles" are growing more and more numerous along our country roads. These auto trucks, carrying good-sized collections of books in the care of trained librarians, make trips into rural and outlying regions, where they stop by the side of the road to let people living round about come and make a selection.

The First Children's Library

One of the most important phases of the work of a modern public library is its service to children and the schools. The first children's library was probably the one organized in the little town of West Cambridge, Massachusetts, in 1835, though there is a record of a juvenile library in Lexington, Massachusetts, as early as 1827. The West Cambridge library was founded upon a gift of a hundred dollars left for the purpose by a physician, Dr. Ebenezer Learned, who wished to express his appreciation of the hospitality the little village had shown him when he was a young man. It was some time before his idea spread to any extent. A children's library was established in New York City in 1885, and five years later a room was set aside for children in the Public Library at Brookline, Massachusetts. The separate room finally was recognized as the best way to house the children's section of a public library.

A Library's Work for Young People

To-day nearly all large libraries have a separate children's department, which conducts work in the branches as well as in the main library. Especially trained children's librarians organize children's clubs of various sorts, conduct story hours, teach children how to use the library, and help them in reference work and in choosing books. Lately a number of libraries, especially the larger ones, have set up "intermediate" and

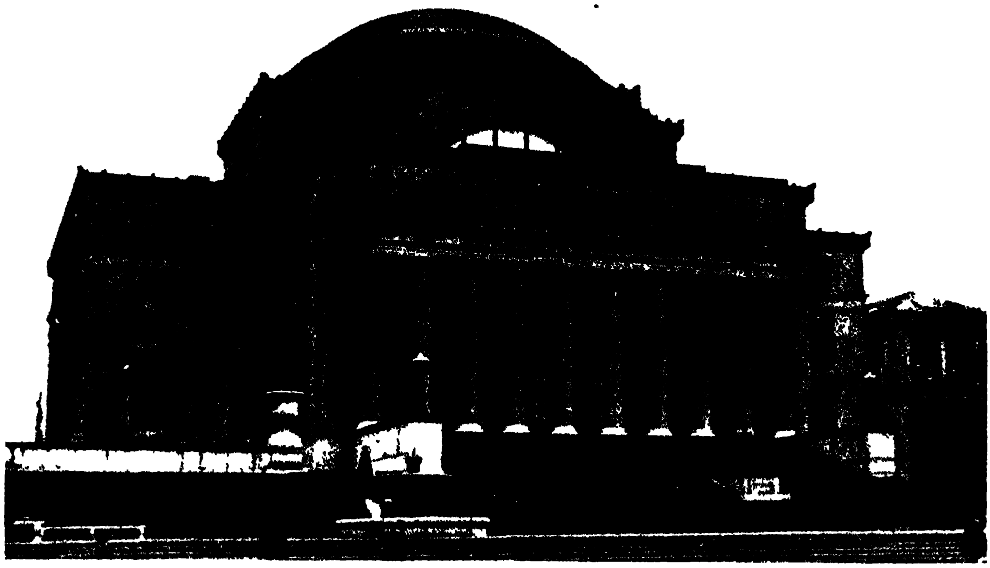


Photo by the Keystone View Company

The varied fortunes of the library of Columbia University show well what the development of libraries has been. To-day this great collection, one of the finest in the world, contains over 2,000,000 volumes. But in the early days before the Revolution, when Columbia was little King's College down on Park Place, at the lower end of Manhattan Island, the whole of the college library was housed in a single room. It suffered sadly during the Revolution. Unlike many colonial colleges, King's College had been founded by royal charter, and Myles Cooper, its president, was an ardent Tory. To be sure, he did not have things all his own way, for his views were constantly challenged by a brilliant and patriotic young sophomore named Alexander Hamilton. It is only fair to say that Hamilton was loyal to his college as well as to his country, and that when a crowd of angry patriots gathered in front of the building demanding that President Cooper come forth, the young Hamilton held them with an effective flow of oratory while Cooper escaped by the back door in his nightshirt. But all Cooper's Loyalist sympathies did not protect his library during the disorder that followed. The books were housed in City Hall and in St. Paul's Chapel. Several hundred of them came to light in the church tower in 1801. But most of the rest had been stolen by the British soldiers and sold to buy liquor. One wonders what may have been the adventures of those lost volumes.

Even after the Revolution the library was slow in growing. When the college moved up to Forty-ninth Street (1857) the collection contained only classical writings and works on theology, history, and science. It had no current literature. The library was open only two or three hours a day, and students were discouraged from using it. The clergyman who was librarian used to brag about the amount saved every year out of the sum appropriated for buying books.

To-day Columbia spends over $1,000,000 yearly upon her libraries, which serve an army of students from all over the world. The volumes are scattered through many rooms and many buildings, though the bulk of the collection is housed in two large structures. Above is the Low Memorial Library (1897), presented to the university by President Seth Low in honor of his father. Some years ago American architects voted it to be one of the ten most beautiful buildings in this country. It was designed by Charles Follen McKim, and was the first building on Columbia's present campus on Morningside Heights. To-day only rare books and special collections are housed in it, for in 1934 Columbia opened the Nicholas Murray Butler Library, designed by James Gamble Rogers. It has many reading rooms, a theater, a library school, and a large number of private studies for the use of individual scholars—in addition to space for a possible 4,000,000 books. Large as it is, it will soon be inadequate. Already it is crowded.

"senior" collections, quite distinct from the books written for younger children. These intermediate collections are usually intended for the use of junior and senior high school students, and sometimes for young people of college age.

Besides all this, the children's department does all it can to help the work of the schools. Children's librarians go to the classrooms to give interesting talks about books; they give advice to the teachers; they help plan programs for summer reading. In short, they do everything in their power to make the children realize that the library is theirs, and to teach them how to use it. For a long time libraries have been sending small collections of books to the school classrooms, to be changed from time to time as the study

progresses. When a grade school or high school has a library of its own, maintained as part of the school system, the public library often gives valuable service in preparing orders, and in marking, classifying, and cataloging books. It may even supervise the work of the school library, which of course is in the school building and is designed to be of especial help in school work. Large numbers of grade schools have such a library, and accredited high schools are required to have one.

Most large public libraries give special help to teachers. Often they have a teachers' room, where all sorts of books and magazines of interest to teachers have been gathered together. In the same way they are likely to have a business department and a civics department for the use of business men and all who are interested in public affairs

What Is a "Talking Book"?

Then there is a library's work for the blind. For some years the larger libraries had books for the blind, but it was not until 1931 that a law was passed providing that the United States government supply such books through the Library of Congress. Now most of the large libraries administer these collections for a wide area. Books in Braille (brāl) and Moon type are sent to people living many miles from the library, and the mails carry such books free of charge. In some cases teachers are sent to the home to help the blind person learn to read. Besides books in Braille, libraries keep what is known as the "talking book." This is a series of phonograph records on which a book has been recorded for the use of the blind, who have only to play the records on their own machines or on machines rented from the library or loaned by philanthropic groups.

Hospitals too are not neglected. Weekly shipments of books are sent them and librarians visit the patients to help them choose books. Sometimes a library will send a hospital a collection to be kept for six months or a year and administered by a member of the hospital staff, with occasional visits from a librarian. In children's hospitals a trained children's librarian makes weekly visits to distribute books and perhaps tell the children stories. Some hospitals, of course, have their own librarians and library staffs.

Helping in Adult Education

Adult education has made heavy demands on the modern library, both for advice in courses of study and for individual help in reading along especial lines. The library will make out a course of reading to guide a student in covering any desired subject and will put books on reserve for use as they are needed. Of course people of all types and ages avail themselves of this valuable help.

For the general public any library has all sorts of interesting exhibits. It will arrange for talks before schools, women's clubs, and other groups, will take part in conventions and conferences, will associate itself with the business of a locality, and will use the radio to tell the people what it has for them.

Such a library, supported by taxation and open to all the people, who may examine books on the shelves and then take them home, is very different from the little association libraries that were its forerunners. Its aim is to serve the people, young and old, sick and well; and in order to serve them it will take its wares to out-of-the-way communities. And not only that, it draws people of all classes to its bright and comfortable rooms, for it has taken a leaf from the book of modern business and advertises its services through window exhibits, book displays, lectures, newspaper articles, and radio talks. Our country would be a vastly different place to-day if it were not for our public libraries.

The World's Famous Libraries

There are a number of famous libraries in the modern world. One is the British Museum in London. It contains over 4,000,000 books and manuscripts, and receives a copy of every publication printed in the United Kingdom. The Bibliothèque Nationale (bē′blē′ō′tĕk′ nä′sē′ō′näl′), or National Library, in Paris is another famous modern library. It dates back to the fourteenth century, and contains over 4,500,000 books, together with many manuscripts and prints. The Soviet Library in Leningrad is

another national library which contains priceless treasures in books and manuscripts collected by the czars for the early imperial libraries. It is the largest collection in the world.

America's Great Library

In our own country the largest and most famous library is the Library of Congress at Washington, D. C. It was begun in 1800 in a single room, and has grown to be one of the great libraries of the world. It is especially rich in history and early American material. In 1930 it added an extremely valuable collection of what are known as incunabula (ĭn'kū-năb'ū-lȧ) - that is, books printed before 1500 A.D. The Library of Congress contains more than four and a half million books and pamphlets, and nearly three million other items, including prints and music. It is constantly growing, for under the copyright law it must receive two copies of every book published in the United States.

Besides the public libraries there are a certain number of great specialized libraries which are public in the sense that any qualified person may use them. They are not tax-supported, and are usually maintained by an endowment left by the man who started the collection. In the United States we have, for instance, the Henry E. Huntington Library at San Marino, California, noted for its book and manuscript collection of English literature and for its early American material. The Henry C. Folger (fōl'jẽr) Library in Washington, D. C., contains one of the world's finest collections of Shakespeare editions. The John Crerar Library in Chicago, the Newberry Library in the same city, and the Pierpont Morgan Library in New York are all great collections privately endowed but devoted to public use.

The American Library Association

The beginning of the modern public library movement as we know it to-day may be said to date from 1876, when the American Library Association was organized. Official headquarters were at one time in Boston but are now in Chicago. This association is constantly working to extend and improve the great service that libraries give to the people. It has accomplished great things, but is constantly trying to raise the standards of libraries everywhere and to bring the priceless companionship of good books to the millions of Americans who still have no library service within easy reach.

To help achieve its end it has supervised the development and accrediting of library schools for the training of librarians in all fields. Since the establishment of the first library school at Columbia University (1887), twenty-five others have been added to the list, and standards in all of them are constantly being raised. In some of its work the association has the use of funds donated by the Carnegie Corporation. On other pages we have told of the great work of Andrew Carnegie (kar-nā'gĭ) in establishing public libraries throughout the land.

Do You Know How to Use a Library?

In order to feel at home in one of our libraries to-day one needs to know a little about how to use it. It is not enough that you may go to the open shelves and select a book, though that is a great advantage which a borrower did not have in the earlier libraries. It was much harder to make a selection when you had to go to the catalog, fill out a slip, and wait for the book to be brought you before you could tell whether or not it was what you wanted.

But no large library can put all its books on open shelves, so one needs to know how to choose books from the catalog. Somewhere in a convenient spot in any library you will find a large case containing rows of drawers. In the drawers are files of cards, a card for every book in the library, and for pamphlets, magazines, and other material as well. Books in the card catalog are arranged alphabetically under the authors' names. In the upper left-hand corner of the card is the book's "call number"—a number assigned it under a very simple and useful system of classification. Often this is the Dewey decimal system, devised by Melvil A. Dewey, a pioneer in library work. The introduction of this system was an important forward step in the development of libraries in this country.

The Dewey system divides the field of knowledge into ten great divisions as follows:

000 to 099 General Works
100 to 199 Philosophy
200 to 299 Religion
300 to 399 Sociology
400 to 499 Language
500 to 599 Science
600 to 699 Useful Arts
700 to 799 Fine Arts
800 to 899 Literature
900 to 999 History

Each of these classifications is again subdivided until we have each number standing for some definite subordinate classification. For instance, 500 is for science in general; 580 is for botany, a division of science; 582 is for trees, a division of botany. If you wished to record a subdivision under trees, you would put a decimal point after 582 and then add a number for your subclass. In this way one may bring a classification down to as small a division as seems necessary by adding more numbers to the right of the decimal point.

The Letters in the Call Number

In many libraries there will be one or more letters and numbers below the first row of numbers in the call number. These letters are the first or first and second letters in the author's last name or in the name of a series of books to which your book may belong. The numerals that follow belong to a particular work by this author or a particular work in the series. Let us suppose you find 973.2 Os31, as the call number for Professor Herbert L. Osgood's work, "The American Colonies in the Seventeenth Century." As we have said, 973.2 will refer to this particular phase of American history. "Os" are the first two letters of Professor Osgood's name, and "31" shows which one of his works this is. Every publication has its own number.

How to Draw a Book from the Library

On your card you will find, besides the call number, the name of the author with the surname given first -the title of the book, the name of the publisher, the place of publication, and the date of the present volume. Then there will probably be information as to the size and shape of the book and perhaps as to its contents. There frequently is still further information about the work. If you make up your mind that you would like to see it, you will make out a slip bearing the call number, the author's name, the title of the book, and your own name. An attendant at the loan desk will get you the book. This simple process has put in your hands an instrument of knowledge that not even kings could command a few centuries ago.